ANALYSIS OF ORGANIC CONTAMINANTS AND THE PHYSICO-CHEMICAL PROPERTIES OF BOREHOLE WATER OF MAILI-NNE ESTATE AND SOSIANI VILLAGE, UASIN GISHU COUNTY, KENYA.

By:

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Award of Master of Science Degree in Analytical Chemistry, Moi University.

2016

DECLARATION

DECLARATION BY THE STUDENT

I hereby declare that this thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

Dedicated to my parents who taught me the strategy of simplicity, my husband Cornelly Serem for his financial support and my children (Coem, Laureen, Sheryl and Dylan).

ABSTRACT

The noxiousness of pesticides as well as their harmful environmental effects have generated interests in the identification and quantification of organic contaminants in borehole water. These contaminants can move from agricultural land or poorly managed

sewerage systems and get into drinking water by surface runoff or by leaching into groundwater. The study sought to analyze the organic contaminants and their effects on physico-chemical parameters of borehole water of Maili-nne; a residential area and Sosiani, an agricultural area. This was through detection of organic contaminants in borehole water; quantification of the detected organochemicals; and establish the impacts on the physico-chemical properties of borehole water of Maili-nne and Sosiani areas. Fifteen boreholes, five at Maili-nne (MB1-MB5) and ten at Sosiani (SB6-SB15) were systematically selected and water sampled during the dry and the wet seasons. Organic contaminants were analysed by detection and quantification of organic pesticides and plasticizer based on retention times by High Performance Liquid Chromatography (HPLC) and Gas Chromatography–Mass Spectroscopy (GC-MS) in correlation to computed element libraries for quantification. Their impact on pH, turbidity, colour and Biological Oxygen Demand (BOD) were probed using pH meter, turbidity meter, colour disc and BOD meter, respectively. The nutrients, sulphates and nitrates were analyzed using ultraviolet spectroscopy (UV-Vis). Diazinon was detected in boreholes SB9, SB12 and SB13, with highest level of 2.21 mg/L during the dry season and 1.52 mg/L in the wet season. Fenitrothion was detected in MB1 (0.145 mg/L and 0.191 mg/L) during the dry and the wet season, respectively. Malathion was found in SB6 and SB15 at 0.207 mg/L and 0.940 mg/L, respectively only during the dry season. Cyhalothrin concentration in MB1, SB7 and SB9 were 0.11, 1.25 and 1.47 ppm, respectively during the dry season and 1.37, 1.31 and 1.21 ppm, respectively during the wet season. The concentration of bis (2-ethylhexyl) phthalate in the 15 boreholes ranged from 0.00 µg/L to 0.172 µg/L. Dimethoate was only detected in Sosiani (SB7) during the wet season. Sulphates concentration ranged between 0.00 -28.3 mg/L during the dry season and 1.06 - 66.44 mg/L during the wet season in Maili-nne and Sosiani. Nitrates concentration ranged between 0.31 - 22.8 mg/ L in the dry and the wet seasons. Physico-chemical properties of the water were found to be higher and others lower than WHO standards. The pH of the borehole water was in the range 5.45 - 5.92. Turbidity ranged between 1.32 - 3.08 NTU and 1.23 - 6.42 NTU during the dry and the wet seasons, respectively. BOD values ranged from 1 - 40 mg/L in the wet season and 0 – 8mg/L during the dry season and were significantly lower in Sosiani than in Maili-nne during the wet season. It can therefore be concluded that residues of some organic contaminants were above the WHO standards leading to decrease of water pH during the dry season beyond WHO limits (pH 6.5). The study also established that there was a positive significant correlation between presence of organic contaminants and deviation of physico-chemical properties (p=0.016, rho=0.68) in Maili-nne and Sosiani. In this regard the borehole water in the study areas should be treated and awareness be made on the impacts of pesticides use.

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ACKNOWLEDGEMENT

I wish to express my gratitude to all who worked tirelessly to make this work possible. The assistance, encouragement from my supervisors, Dr. Jackson Cherutoi and Prof. Samuel Lutta, is highly acknowledged. Special thanks go to the technical staff in the laboratories where I conducted the research for their assistance in the laboratory. I am deeply indebted to the government chemist and the Kenya Industrial Research and Development Institute, specifically Mr. Collins Anditi and Mr. Johnstone Kibet for their support that enabled me to carry out my laboratory work in their laboratories.

To the entire Serem's family for their moral, spiritual and financial support that they have given to me so far. I appreciate the comfort they offered to me during unbearable times. My heartfelt gratitude goes to my friends especially Joyce and my other classmates for their support that enabled me to do this work. Above all, am grateful to God who has made everything possible.

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
APHA	American Public Health Association
BOD	Biological Oxygen Demand
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
GC-MS	Gas Chromatography-Mass Spectrometer
HPLC	High performance Liquid Chromatography
HU	Hazen Units
MAC	Maximum Allowable Concentration
MPL	Maximum Permissible Level
MRL	Maximum Residual Limit
NEMA	National Environmental Management Authority
NTU	Nephelometric Turbidity Units
PCE	Perchloroethene
Pt-Co	Platinum-Cobalt scale
P-MPL	Primary Maximum Permissible Level
SDWA	Safe Drinking Water Act
S-MPL	Secondary Maximum Permissible Level
TCE	Trichloroethene
UV	Ultra Violet
VC	Volatile Compounds
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Water is very essential to human life. Among the sources of water, borehole water accounts for up to 88% of water used domestically in Africa's homesteads, semi-urban and urban areas. In many developing countries, availability of water has become a critical and urgent concern to people depending on non-public water supply (Okonko *et al*., 2008). These boreholes are prone to contamination by various substances mainly organic contaminants originating from increasing use of pesticides and herbicides. Infiltration of effluent from sewage treatment plants from urban areas, municipal waste and ponds are other sources of contaminants. All these contaminants do affect physico-chemical properties of borehole water like pH, colour, turbidity, and Biological Oxygen Demand (BOD) (S'aeed & Amira, 2013).

Analysis of the level of organic contaminants and physico-chemical properties of water has been used to assess the quality of borehole water. The presence of specific components or whole of the contaminants originating from specific areas like; organic contaminants from agricultural pesticides and herbicides in borehole water confirm pollution (Omwaye *et al.,* 2014).

Besides agricultural and sewage treatment effluents, Sharma (2004) explained that the quality of borehole water can be influenced by reactions that act on the water from the time condensation takes place in the atmosphere to the time it is discharged by a well.

Groundwater pollution due to pesticides is a worldwide problem (Zhou *et al*., 2006). This is due to the possible adverse effects of the organic contaminants to human health. The toxic pesticides constituents and their metabolites find their way through various means into the groundwater hence influencing the quality of borehole water. The organic contaminants therefore affect the physico-chemical properties (Lema *et al*., 2014).

In most of the developing countries in Africa, the increasing pesticides use has led to organochlorine, carbamates, organophosphorous, pyrethroids and atrizines organic contaminants finding their way to borehole water (Agrawal *et al* ., 2010). In addition, the use of nitrogen and sulphate fertilizers in agriculture has contributed to surface and underground water pollution (Wan *et al*., 2005). Local industries have also been noted to commonly use tetrachloroethene and Trichloroethene (TCE) as solvents. Due to poor storage and disposal of these solvents, contaminants find their way through various means into borehole water. Nutrients from the agricultural farms lead to eutrophication of water bodies (Kalff, 2002; Nanga *et al*., 2011; Kulekana, 2014).

In a study by Nwinyi (2011) on assessment of water quality in Canaan land, Ota, Southwest Nigeria, established that BOD levels ranged between 0.3 mg/L and 0.4 mg/L which were much lower than the WHO standards. This variation of water BOD was attributed to agricultural activities in that area. Elsewhere, Kamrin (2010) found out that

underground water bodies up to 8 KM from a green house in which the plants were sprayed with insecticides, diazinon residue level was far above the WHO standards.

Improper pesticides use has dire implications on human health with most of them being classified as carcinogenic, cholinesterase inhibitors while others are suspected to be endocrine disruptors. Aldicarb, carbofuran, cypermenthrin and dimethoate are classified as possible human carcinogens and cholinesterase inhibitors (Lema *et al*., 2014). The improper use of these pesticides is therefore currently cited as the cause of various forms of cancer, birth defects, sterility, damage of the liver, kidney, neural organs and deaths experienced in the population (Ngowi, 2002; McCauley *et al*., 2006; Soltaninejad *et al*., 2007; Weiss, *et al*., 2007; Aktar *et al*., 2009).

In reference to this background, the present study therefore sought to determine the presence and level of organic contaminants and their impact on physico-chemical properties in borehole water in Maili-nne a residential area for medium level income population and Sosiani an agricultural area in Uasin Gishu County, Kenya.

1.2 Problem Statement

The noxiousness of pesticides as well as their harmful environmental effects have inspired concerns and the will of identification and quantification of pesticides in water (Pinheiro & Andrade, 2009). Pesticides usually move from agricultural land and get into drinking water by surface runoff or by leaching into groundwater. Pesticides applied to agricultural land may also become airborne during application and drift great distances in the air ultimately resulting in contamination of surface water that later gets into the borehole (Pinheiro & Andrade, 2009).

Maili-nne and Sosiani areas are situated in Uasin Gishu County which is part of western zone of Rift Valley where phonolite lavas are resting directly on the basement system of rocks. This geological setup potentiates contamination of groundwater due to the presence of organic contaminants originating directly from agricultural herbicides, pesticides and commercial fertilizers that may influence the level of pH, turbidity, BOD and colour of the borehole water.

Maili-nne is a residential area for middle class community situated on the lower side of the farming area making its boreholes prone to pollution. Sosiani is a prime agricultural land driven by large scale grain farming, dairy farming and flower farming where pesticides and herbicides are rampantly used. Routine level monitoring of organic contaminants and physico-chemical properties of borehole water in the two areas is very imperative. This is because they are situated in an agricultural area where pesticide and herbicides use could be intense.

1.3 Justification

Although many countries especially developed countries have banned the use and improper use of harmful organic substance in agriculture, others especially the developing countries in Africa, including Kenya still use these harmful substances since agriculture is the source of livelihood (Tanabe, 1993).

Maili-nne in Eldoret is a residential area densely populated and situated near a number of manufacturing plants, including Raiplywoods, maize millers and steel mill factory. Sosiani area in the periphery of Eldoret is surrounded by flower farms, maize farms and wheat plantations. There is a high possibility of the pesticides, insecticides and fertilizers

ending up into water bodies e.g. boreholes, through run off and wind blow. These chemicals cause borehole water contamination, posing a great hazard to water consumers in these particular areas. This organic and inorganic contamination can cause very adverse effects ranging from acidosis, alkalosis, kidney problems, and liver problems to even incurable concern (Clark, 2003). Although these effects may not be currently rampantly witnessed, routine monitoring of the contaminants if appropriately carried out by studies such as this one will assist a great deal in informing policy makers on the same.

1.4 Objectives

1.4.1 General Objective

To evaluate the impact of organic contaminants on physico-chemical quality of borehole water in Maili-nne and Sosiani areas

1.4.2 Specific Objectives

i. To determine the presence of organic contaminants and the levels of detected organic contaminants in borehole water of Maili-nne and Sosiani areas

ii. To determine the physico-chemical properties of borehole water of Maili-nne and Sosiani areas

iii. To ascertain the correlation between organic contaminants and physico-chemical properties of borehole water

1.5 Scope of the Study

This study was conducted in Maili-nne and Sosiani areas between the months of January and October 2015. Water samples were obtained from 15 boreholes, 5 boreholes at Maili-

nne which is a residential area situated on the lower side of the agricultural area, and 10 boreholes from Sosiani where agriculture is practiced. The selection of the two areas of study was based on the fact that in Sosiani area, the residents practice farming and Maili-nne estate is a residential area situated near factories, dumpsites, sewerage management and farming areas that may contaminate the borehole water.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Ground water

During the rainy season, some of the water flows on the land surface into rivers, lakes and streams while some of the water evaporates into the atmosphere and the mainstream

water seeps into the ground (Clark, 2003). The water that finally gets into the soil is utilized by plant and soil organisms while the water not used moves deeper into spaces in the ground. This water then moves downwards through cracks in the soil and fractures in rocks until it is intercepted by an impermeable layer of clay or rock (Maule *et al*., 2007). The water then accumulates on this layer filling up all available spaces until saturation. The top of the impermeable layer becomes the water table while the accumulated water becomes the ground water (Lema *et al*., 2014).

Groundwater contamination is due to changes in land usage, such as the clearance of vegetation, over-abstraction of groundwater or excavation below the water table (Tredoux *et al.*, 2004). Groundwater pollution not only affects the quality of water but it also threatens human health, economic development and social prosperity (Milovanovic, 2007). `

Pesticides are used for the control of weeds, pests and diseases in plants, external vectors of veterinary or medical diseases of man or domestic animals for the protection of any food intended for human consumption (Lema *et al*., 2014). Pesticide properties such as solubility, adsorption, volatility and potential degradation play a significant role in the contamination process of ground water (Njoroge *et al*., 2016). These pesticides are known to cross the placenta barrier e.g. organophosphate pesticides was detected in the amniotic fluid surrounding the foetus, posing great danger to the development of the brain (Aliyu, 2015).

2.2 Chemical composition of ground water

Groundwater is abstracted through hand-dug wells, hand pump operated shallow wells and submersible pump operated deep well or boreholes (Tredoux *et al.*,

2004)..Groundwater is often high in mineral content such as magnesium and calcium salts, Iron and Manganese depending on the chemical composition of the stratum through which the rock flow (Zahedeh *et al.*, 2010). By the time precipitation has gone through soil sediments and rocks to refill the ground water, it has accumulated a hundred times those amounts of dissolved substances (Aharma, 2004).

The physicochemical properties of pesticide compounds, particularly their solubility in water and organic solvent, characterized by their octanol-water partition coefficients determine their character of leaching into groundwater (MacBean, 2015). The solubility varies with the acidity of the water and the amount of oxygen dissolved in it and groundwater readily dissolves the most soluble minerals in rocks (Njoroge *et al*., 2016). Nitrogen (N) in natural waters is found in combined form as nitrates and nitrogen generated from soil forming processes dissolve in water to form nitrogen compounds (NO_2 and NO_3^-). Nitrates may be reduced to nitrite through the biological process of denitrification in anaerobic conditions (Jurewicz, 2006).

Nitrate –nitrogen (NO_3-N) in ground water may result from point sources such as sewerage disposal systems and livestock facilities and non point sources such as fertilized cropland (Anwar & Vanita, 2014). Carbon dioxide (CO_2) in groundwater normally occurs at a much higher partial pressure than in the earth's atmosphere and when ground water is exposed to the atmosphere, CO_2 will escape and the pH will rise (Anwar & Vanita, 2014). Clay minerals found in rocks and sediments are usually linked with large amount of sodium during deposition in offshore marine environments. Cations exchange occurs between calcium and magnesium from the water rich in sodium bicarbonate. According to Aharma (2004), studies of carbon in groundwater using radiometric dating have shown

that its age can be as long as 10,000 and 40,000 years in the deeper part of a number of aquifers.

The sulphate content in water is important in determining the suitability of public and industrial supplies and higher concentration can cause malfunctioning of alimentary canal and show cathartic effect on human beings (Lenin & Saseetharan, 2008). Sodium chlorides which are very soluble in water are not flashed out from ground water but no adverse effects on humans have been reported from intake of water containing highest content of chloride (Singh *et al*., 2011). Many hydrologists in the past thought that the brine pumped from deep wells were ancient marine water taped in sediments as they were laid down. It is now clear that ground water can develop to become more saline with depth and age (Merritis, 2008).

2. 3 Contaminants of ground water

There are a number of important factors that determine whether a chemical is likely to reach and become groundwater contaminant. These major factors include; properties of the chemical, properties of the soil, existing conditions at the site and human actions (Agrawa*l et al*., 2010).

2.3.1 Agricultural chemicals and water quality

Water pollution occurs in many forms, from a wide range of sources. Agriculture may contribute to water pollution from feedlots, pastures, and croplands (Agrawal *et al*., 2010). Solubility is a chemical property that shows how readily a chemical dissolves in water. Water moving down through soil carries water-soluble chemicals with it and leaching occurs always as water moves from the surface down to the groundwater aquifers (Agrawal *et al*., 2010). A chemical that is held tightly by soil has high absorption

and it is not likely to be carried away by leaching. Volatility determines the ability of a chemical to get lost to the atmosphere. Since the groundwater belong to the hydrological cycle, highly volatile chemical may escape to the atmosphere before it dissolves in water except for the water soluble chemicals (Baedecker, 2002).

Pesticide chemicals that dissolve readily in water are highly soluble and have high tendency to leach from the soil to groundwater (Njoroge *et al.*, 2016).

2.3.2 Soil properties and water quality

Highly permeable soils have a greater capability to lose chemicals through leaching, therefore application of pesticides or fertilizers to this type of soil should be done in a way that leaching is reduced (Odeyemi, 2011). Texture, permeability and organic matter content are important characteristics of soil which determine groundwater contamination (Dores *et al*., 2008). Once pesticides enter the soil, a portion adheres to soil particles and some remain in solution in the soil water (Gavrilescu, 2005). Soil/water equilibrium partition coefficient is a ratio between the concentration in soil and the concentration in water (Njoroge *et al*., 2016). Organic matter affects soil capability to hold water and to adsorb chemicals. According to Vandre (2005), the incorporation of organic matter into soil increases the capability and decreases the downward movement of chemicals by leaching.

2.3.3 Water quality and the existing conditions at the site

The depth of groundwater at an exact position is important because the soil between the surface and groundwater acts as a filter. When the soil between the surface and groundwater is less, it increases leaching, decreases adsorption and degradation (Vandre,

2005). When groundwater is close to the surface, minor application, spilt application or no application of pesticides or fertilizers may be the best alternative. The geological conditions of a site should be determined to assess groundwater susceptibility. Layers of gravel above the groundwater area do not offer much protection against percolation or leaching while a layer of clay does generate a useful filter for many chemicals (Wan *et al*., 2005). Climate, for example as the high mean air temperatures (monthly means from 22°C to 27°C) favor pesticide degradation, but also enhance pesticide dispersion by volatilization (Dores *et al*., 2008). Cold soil slows down the rate of degradation and increase the time the chemical is available for leaching (Vandre, 2005).

2.3.4 Human activities and water quality

Most human activities involve the use of water for food production, as nutrition and are independent on water availability in adequate quantities and good quality (Howari, 2005). Groundwater is said to be polluted when its quality is degraded as a result of man's activities to an extent that it becomes less suitable for its intended use (Chapman, 1992). Human life style manifested by the low level of hygiene practiced in developing nations threatens ground water resource (Ikem *et al*., 2002). Pollution of water is due to increased human population, industrialization, use of fertilizers in agriculture and man-made activity (Rao *et al*., 2012). Timely application of pesticide is very important prior to heavy rains or irrigation may result in leaching rather than effective use (Laskowski, 2002).

2.4 Sources of ground water pollution

Water pollution is the contamination of water bodies (Agrawal *et al*., 2010). Pesticide chemicals such as herbicides, insecticides, fungicides, rodenticides, molluscicides; are

agricultural sources of borehole contamination (Agrawal *et al*., 2010). Agricultural land that lacks sufficient drainage is considered by many farmers unproductive and this has led to installation of drain tiles or drainage wells to make the land more productive. Changes in land usage such as clearing of vegetation, over-abstraction of ground water or excavation, below water table can also contribute significantly to ground water pollution (Tredoux *et al.*, 2004).

The use of excessive pesticide in agriculture may lead to contamination of groundwater by drift, runoff, drainage and leaching (Zahedeh *et al.,* 2010). Chemicals such as fertilizers, herbicides, insecticides and fungicides when over-applied in the crop field could also introduce these contaminants into the ground water (Zahedeh *et al.*, 2010). Nitrates are an important plant nutrient and its level in natural waterways is very low. Excess amounts of nitrate can cause water quality problems by accelerating eutrophication. It also contributes to the illness called methemoglobinemia in infants (Zhang, 2007). Contaminants from garage or farm equipment sheds include; paint containing lead and barium, gasoline and oils containing volatile organic compounds (Pyne, 2005).

Groundwater contamination is from several sources (USGS Circular 1988) including agricultural activities, storage tank leakage, industrial waste, sewer and septic leakage, leaching from landfills, mining and other sources (Agrawal *et al*., 2010). The abandoned boreholes not in use and have not been plugged or dismantled provide a direct route for water to flow directly from the surface into the ground water. Boreholes without a cap can become contaminated by the working fluids such as grease and oils from the pump or from the surface if the borehole cap is not tightly closed or incase the lining of the

borehole is cracked or corroded. In addition, many older farm boreholes have merely shallow holes dug into the ground. These boreholes can easily be contaminated and are also a safety hazard to children and animals (USEPA, 2007).

2.4.1 Industrial sources of groundwater contamination

Modern economic activities require transportation and storage of materials used in manufacturing, processing and construction (USEPA, 2007). During transportation, some of these materials can be lost through spillage, leakage or improper handling. Cleaning of spills may pose a threat to ground water when the spills are not cleaned using absorbent substances.

Other industrial sources of contamination include wastes from the holding tanks or spraying equipment cleaning water disposed on an open surface (USEPA, 2007). Mining, petroleum drilling, landfills may also be major sources of ground water pollution (Cook *et al.,* 2012). These floor drains may be connected to shallow injection well systems, which are not anticipated to handle the industrial chemicals typically used by businesses (Anwar & Vanita, 2014). The problems stem from the mining process itself, disposal of wastes and processing of the ores and the waste it creates (USEPA, 2007).

2.4.2 Domestic sources of ground water contamination

Effluent from septic tanks and cesspools are major causes of ground water contamination and its misuse by disposing anything other than domestic or sanitary waste can cause an extensive threat to ground water (Manjare, 2010). Waste water from residential areas can be a source of many categories of contaminants including bacteria, viruses and nitrates from human waste and organic compounds injection wells are of particular concern to

ground water quality if located close to and up gradient of drinking water boreholes (Freifelder, 1985). Household chemicals such as paints, synthetic detergents, solvents, oils, medicines, disinfectants, pool chemicals, pesticides, batteries, gasoline and diesel fuel if not stored or disposed properly can lead to ground water contamination. Garages or basements with floor drains, spills and flooding may introduce such contaminants into the ground water because community landfills are not prepared to handle hazardous materials. Similarly, waste dumped or covered in the ground can contaminate the soil and leach into the ground water (Manjare, 2010).

In urban areas, there is an increase of paved surfaces and this has led to increase in rain runoff. Storm water drainage wells are not used by municipalities to dispose of this additional runoff particularly if the area is not served by storm sewers nor has a limited sewer system. The cheaply dug boreholes and landscaped areas, storm water drainage wells that communities use to control water during storm events cause a threat to ground water particularly in areas with a high water table (Freifelder, 1985). Fertilizers, herbicides, insecticides, fungicides and pesticides applied to the grass and backyard contain hazardous chemicals that can pass through the soil and contaminate the ground water (Maule *et al*., 2007; Wan *et al*., 2005; Ntow *et al*., 2008). In the garage, items that are not properly used, stored or disposed off may potentially contaminate ground water especially if there is a drain to the ground in the floor of the garage. The contaminants from the garage include; batteries that contain lead, cadmium or mercury and paint containing lead and barium, gasoline and oils containing compounds, barium from diesel fuel combustion (Toman *et al*., 2009).

Waste water from residents that are directed to a septic system or sewer system may contain detergents from dishwashing and laundry, organic compounds from garbage, disposal bacteria, nitrates, and sulphates from sewage, greases and oils (Ntow *et al*., 2008). Grass with excess or misapplied fertilizers, herbicides and fungicides may bring these contaminants such as, tetrachloride and heavy metals, such as manganese into ground (USEPA, 2007).

2.4.3 Natural sources of ground water contamination

Ground water contains some impurities even if it is not affected by human activities. The type and concentration of natural impurities depends on the following; nature of the geological materials through which the groundwater moves and the quality of the recharge water (USEPA, 2007). Ground water moving through sedimentary rocks and soils may pick up a wide range of compounds such as magnesium, calcium and chlorides. Some aquifers have high naturally concentration dissolved constituents such as arsenic, boron and selenium. Ground water pollution not only affects water quality, but it also threatens human health, economic development, and social prosperity (Milovanovic, 2007). Naturally occurring contaminants include; Aluminum, arsenic, barium, chloride, chromium, coliform bacteria, copper, fluoride, hardness, iron, lead, Manganese, mercury, nitrate, selenium, silver, sodium, sulphate, zinc and their effect on ground water depends on the type and its concentration (USEPA, 2007).

2.5 Organic contaminants

The term “organics” means compounds that have the element carbon as a major constituent (EFC, 2009). Organic compounds can be of various types and have numerous origins. Some organics in borehole water are caused by the decay of naturally occurring

vegetation. These decay compounds are called lignin or tannins. The presence of these compounds dissolving in water would be part of the natural environmental condition of that water resource (USEPA, 2007).

A much larger group of organic contaminants are the thousands of artificial organic chemicals that have been produced in the last 50 years. The U.S. Environmental Protection Agency (EPA) regulates some of these contaminants as health risks in the Safe Drinking Water Act (SDWA). The upper satisfactory concentration of regulated contaminants in drinking water is called the Maximum Contaminant Level (MCL). These man-made organic contaminants can be grouped into subcategories that are often more recognized and more easily pronounced than the more formal chemical name (Amadi, 2010). These subcategories are given below, along with a few illustrations of specific contaminants in each subcategory.

i. Pesticides such, as organochlorine, organophosphate, pyrethroids
ii. Hydrocarbons, such as benzene, xylene, toluene
iii. Industrial solvents, such as trichloroethylene, carbon tetrachloride
iv. Herbicides such, as alachor and silvex

Pesticides form one of the largest and most important groups of organic compounds used in agriculture. This group include; insecticides, herbicides, fungicides, ascaricides, nematocides, rodenticides, and bactericides. Analytical methods are widely used for the analysis of their formulation, residues and the degradation products in the environment (Amadi, 2010). Flower farms continuously use pesticides and as a result, substantial amounts of pesticides and their degradation products build up in the biota. The types of pesticides and their concentrations which are found in borehole water can be affected by

a number of factors including properties of the chemical application history, season of the year and physical characteristics of the water and the underlying sediment (Carabias *et al.*, 2003).

Pesticides that are sprayed in agricultural land, and in urban areas, become airborne during application and it can move to great distances in the air (Amadi, 2010). A study carried out in the US found out that the commonly used pesticides can be detected far beyond the points of application at a distance of 10 m to 150 m away from the application sites (Figueroa *et al*., 2007). Thus people living in agricultural areas may have a high exposure to the pesticides because of inhalation of pesticide spray drift. According to Carabias *et al.*, (2003), insecticides are grouped in the following groups based on the general formula of the compound.

The following organic pesticide contaminants that are discussed include; Malathion, diazinon, fenitrothion, chloropyrifos, sulfotep, dimethoate (Organophosphate), triallate, lindane, dieldrin (Organochlorine), cyhalothrin (Pyrethroids) and bis (2-ethlyhexyl) phthalate (Plasticizers).

2.5.1Organochlorines

Organochlorine is a group of pesticides that are toxic and remain in the environment for a long time (UNEP, 1993). It is a generic term for pesticides containing chlorine; however, it is commonly used to refer to the older persistent materials including; dieldrin, heptachlor, lindane (Karami & Abdollahi, 2010). An organochlorine pesticide because of their chronic toxicity, persistence, tendency to accumulate in biota and the negative impact on human beings and other wildlife has been a global concern (Zhou *et al*., 2006).

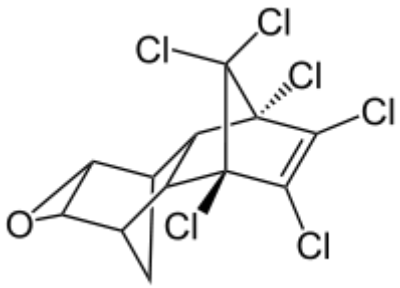
Organochlorine has also been banned for over a decade worldwide, including Kenya. But many are still in use because of their low cost, versatility and availability. Organochlorines have been extensively used and particularly; DDT and Endosulfan for control of maize and cotton pests. Lindane, dieldrin, aldrin, endrin and heptachlor have also been widely used in Kenya, which has made their presence ubiquitous in the environment (Wandiga, 1996).

Dieldrin is an organochlorine originally produced in 1948 by J. Hyman & Co, Denver, as an insecticide (Hatcher *et al.,* 2007). Dieldrin is closely related to aldrin, which reacts further to form dieldrin. Aldrin is not toxic to insects; it is oxidized in the insect to form dieldrin which is the active compound (Kaushik & Kaushik, 2007). Both dieldrin and aldrin are named after the Diels-Alder reaction which is used to form aldrin from a mixture of norbornadiene and hexachlorocyclopentadiene (Funel & Abele, 2013). Originally developed in the 1940s as an alternative to DDT, dieldrin proved to be a highly effective insecticide and was very widely used during the 1950s to early 1970s. Endrin is a stereoisomer of dieldrin (Sadasivaiah *et al.,* 2007).

However, it is an extremely persistent organic pollutant; it does not easily break down. Furthermore it tends to biomagnify as it is passed along the food chain. Long-term exposure has proven toxic to a very wide range of animals including humans, far greater than to the original insect targets. For this reason it is now banned in most of the world (Muir *et al.,* 2006).

Dieldrin has been linked to health problems such as Parkinson's (Kanthasamy *et al.,* 2005), breast cancer (Ambrosone, 2000), and immune, reproductive, and nervous system

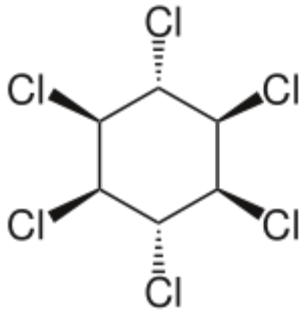
damage. It can also adversely affect testicular descent in the fetus if a pregnant woman is exposed to it (Kanthasamy *et al.*, 2005).



Structure of dieldrin

Lindane also known as gammaxene or Gammallin is an organochlorine chemical variant of hexachlorocyclohexane that is used both as an agricultural insecticide and as a pharmaceutical treatment for lice and scabies (Brandenberger & Robert, 1997).

It is a neurotoxin that interferes with GABA neurotransmitter function by interacting with the GABAA receptor-chloride channel complex at the picrotoxin binding site (Girish & Kunhi, 2013). In humans, lindane affects the nervous system, liver and kidneys, and may be a carcinogen (Pool-Zobel *et al.*, 1993). Lindane is mainly metabolized via various intermediates stages to 1, 2, 4- trichlorobenzene, which is further converted to isomeric trichlorophenols. Excretion occurs after the formation of glucuronate derivatives (Kanja *et al*., 1990). The types of pesticides and their concentrations which are found in borehole and its international trade is restricted and regulated under the Rotterdam Convention on Prior Informed Consent (WHO, 2010).



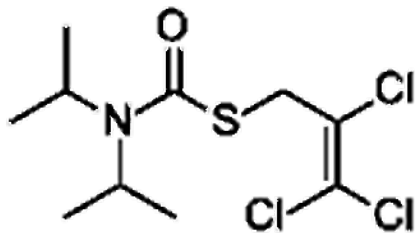
Structure of lindane

Triallate is an organochlorine carbamate derivative commonly used as an herbicide in greenhouses (Albero *et al.,* 2004). It is a pre-emergence selective herbicide used to control grass weeds in field and pulse crops. It is used selectively to control wild oats, black grass, and annual meadow grass in barley, wheat, peas, lentils, rye, maize, beets, brassicas, carrots, and onions. Depending on the crop that is treated, the herbicide is incorporated in the soil before or after planting. Triallate is available as emulsifiable concentrate and granular formulations. It is highly toxic, may be fatal if inhaled, swallowed or absorbed through skin (Karami & Abdollahi, 2010).

Prolonged or repeated exposure to triallate may cause symptoms similar to those caused by acute exposure. Oral doses of 100 mg/kg/day triallate to hamsters for 22 months resulted in decreased body weight, changes in blood chemistry, slight anemia, increased liver weights, and decreased spleen weights (Mosanto, 1989). Mice fed 3 and 12.5 mg/kg/day triallate for 2 years exhibited increased liver and heart weights, changes in the liver and spleen, and mineralization in the brain and cornea (Albero *et al.*, 2004).

Triallate has a moderate persistence in the soil environment. It adsorbs strongly to loam and clay soils and is not readily dissolved in water. This indicates that triallate is not

likely to move through the soil, even though it has an average soil half-life of 82 days (Vencill, 2002). However, if there is significant moisture and low level of organic matter in the soil, leaching and groundwater contamination may be possible. EPA suggests that triallate does not pose a threat to the environment due to leaching because it is generally used where the water table is relatively low (Hartley & Kidd, 1984). Triallate is reported to be degraded in soil primarily by soil microbes (Vencill, 2002). Plants also degrade triallate, lessening its potential to accumulate in the soil (Figueroa *et al.*, 2007). If applied to the soil surface at high temperatures, without incorporation into the soil, triallate can be lost to the atmosphere through volatilization. Its volatility increases with soil water content. Triallate must be incorporated into the soil after application to prevent its loss from soil at high temperatures. Triallate can persist into the next growing season, especially in colder climates in which it is less likely to be broken down (Karami & Abdollahi, 2010).

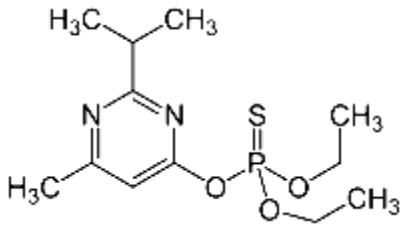


Structure of triallate

2.5.2 Organophosphates

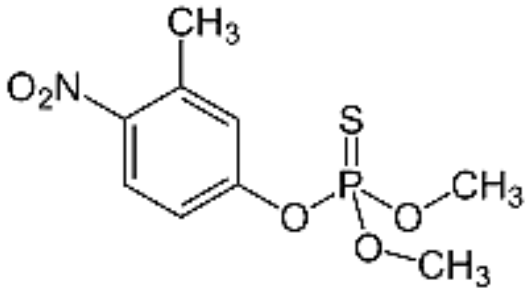
These are all derived from phosphoric acid and are generally known to be the most toxic as compared to the other pesticides to vertebrate animals. They are chemically unstable and they exert their toxic action by inhibiting the cholinesterase enzymes of the nervous system and it results in the accumulation of acetylcholine (Amadi, 2010).

Diazinon is a nonsystemic organophosphate insecticide widely used for general indoor and agricultural pest control (Toman *et al.*, 2009). Diazinon was developed in 1952 by the Swiss company Ciba-Geigy to replace the insecticide DDT (Stenersen, 2004). Residential uses of diazinon were outlawed in the U.S. in 2004 but it is still approved for agricultural uses (Colt *et al.*, 2006). Diazinon is considered to be of relatively high toxicity for vertebrates mainly because it acts as an acetylcholinesterase (AChE) inhibitor once ingested (Wismer & Means, 2012). Studies have shown that exposure to this organophosphate pesticide can result in long-term neurological problems (Walker, 2008).



Structure of diazinon

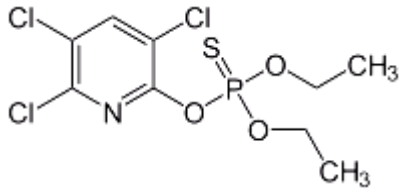
Fenitrothion is an active ingredient found in most phosphorothioate (organophosphate) insecticides (Buttemer *et al.*, 2008). Fenitrothion is also effective against a wide range of agricultural pests and also household insects. It is a non- systemic, and non-persistent pesticide. Acute toxicity of fenitrothion to mammals is considered to be low (Tamura *et al.*, 2001).



Structure of fenitrothion

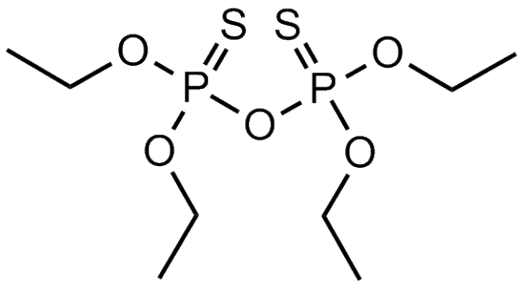
Chloropyrifos is a crystalline organophosphate insecticide. It acts on the nervous system of insects by inhibiting acetylcholinesterase (Seger & Maciel, 2006). Chloropyrifos is moderately toxic to humans, and exposure has been linked to neurological effects, persistent developmental disorders, and autoimmune disorders. Exposure during pregnancy retards the mental development of children (Bebe & Panemangalore, 2003). In agriculture, it remains "one of the most widely used organophosphate insecticides", according to the United States Environmental Protection Agency (USEPA, 2007).

Chloropyrifos is strongly absorbed by soil and does not readily leach from it. It persists in soil for 60–120 days and degrades there primarily through microbial action (Sparks, 2003). The primary degradation product is 3, 5, 6-trichloro-2-pyridinol, which is further broken down to organochlorine compounds and carbon dioxide (Morgan *et al.*, 2005). Owing to its non-polar nature, Chloropyrifos has a low solubility in water and great tendency to partition from aqueous into organic phases in the environment (Kulkarni *et al.*, 2000).



Structure of chloropyrifos

Sulfotep is an organophosphate chemical commonly used as a pesticide in greenhouses mainly as a fumigative agent. The substance is also known as TEDP, dithione or dithiophos. It has a cholinergic effect, involving depression of the cholinesterase activity of the peripheral and central nervous system (Karami & Abdollahi 2010).

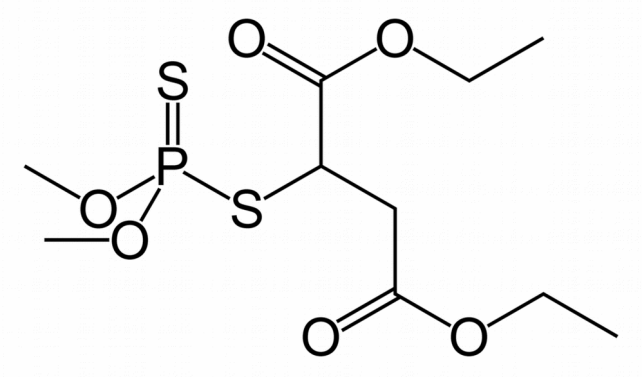


Structure of sulfotep

Sulfotep is made by a reaction from tepp and sulfur. An alternative route can be a reaction of diethyl chlorothiophosphate and water in a mixture of Na_2CO_3. Tepp is made by a reaction of diethylchlorophosphate with water to substitute the chloro-group with a hydroxyl-group. The product can react with another molecule of diethylchlorophosphate to form an ester, the tepp molecule. In this reaction pyridine is often used to clear the reaction from the HCl (Seger & Maciel 2006).

Malathion is an organophosphate parasympathomimetic which binds irreversibly to cholinesterase (Hussain *et al.*, 2005). Malathion is an insecticide of relatively low human

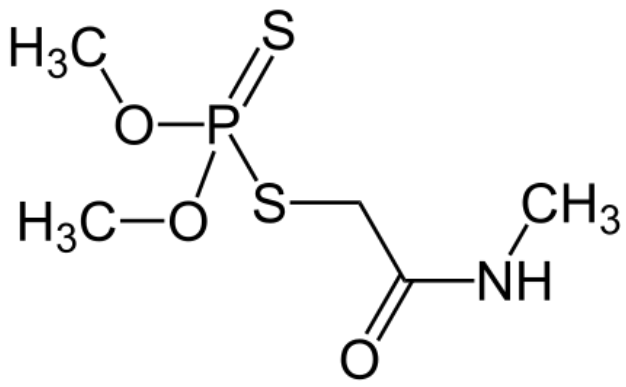
toxicity (Bonner *et al.,* 2007). Malathion as a pesticide that is widely used in agriculture, residential landscaping, public recreation areas, and in public health pest control programs such as mosquito eradication. Malathion itself is of low toxicity; however, absorption or ingestion into the human body readily results in its metabolism to Malathion, which is substantially more toxic (Hussain *et al*., 2005).



Structure of malathion

Dimethoate is a widely used organophosphate insecticide used to kill insects on contact. It is a widely used organophosphate insecticide used to kill insects on contact (Menendez *et al.,* 2010). Dimethoate is one of a class of insecticides referred to as organophosphates. It is moderately toxic by ingestion, inhalation and dermal absorption. As with all organophosphates, dimethoate is readily absorbed through the skin (Hoffmann & Papendorf, 2006). The organophosphate insecticides are cholinesterase inhibitors. They are highly toxic by all routes of exposure. When inhaled, the first effects are usually respiratory-related and may include bloody or runny nose, coughing, chest discomfort, difficult or short breath, and wheezing due to constriction or excess fluid in the bronchial tubes (Tripathi *et al.,* 2003). Skin contact with organophosphates may cause localized

sweating and involuntary muscle contractions. Eye contact cause pain, bleeding, tears, pupil constriction, and blurred vision (Hoffmann & Papendorf, 2006).



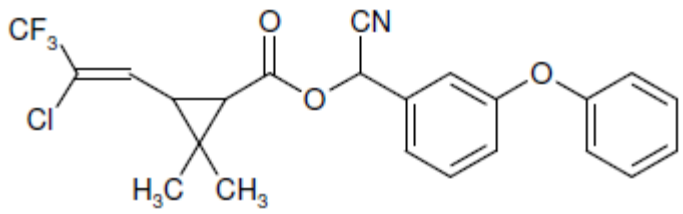
Structure of dimethoate

Heptachlor is a white, crystalline solid with a camphor-like odour. It's a minor and relatively toxic, component of technical chlordane (Schmitt *et al.*, 1985). Heptachlor was first introduced as a contact insecticide in the USA in 1952 for foliar, soil and structural applications (Mukherjee *et al*., 2014). Due to its highly stable structure heptachlor is classified as a persistent organic pollutant (POP). EPA has set an enforceable regulation for heptachlor, called a maximum contaminant level (MCL), at 0.004 mg/L (WHO, 1988).

2.5.3 Pyrethroids

Pyrethroids are organic contaminants with hydrophobicity (log Kow ranging between 5.7 and 7.6) and it has very low solubility (of a few µg/l). Pyrethroids are types of pesticides that tend to rapidly bind to suspended particulate matter or sediments (Laskows KIDA, 2002).

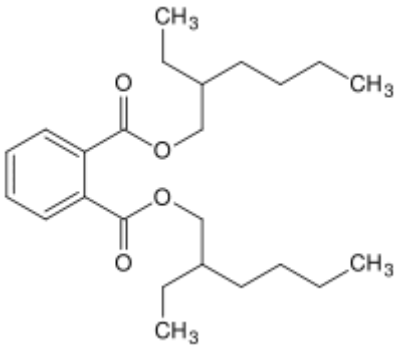
Cyhalothrin is an organic compound that is commonly used as a pesticide (Oudou & Hansen, 2002). It is pyrethroids, a class of man-made insecticides that mimic the structure and insecticidal properties of the naturally-occurring insecticide pyrethrum which comes from the flowers of chrysanthemums (Bennett *et al.*, 2000). Synthetic pyrethroids, like lambda-cyhalothrin, are often preferred as an active ingredient in insecticides because they remain effective for longer periods of time. It is a colourless solid, with a mild odor. It has low water solubility and is nonvolatile. It is used to control insects in cotton crops (Oudou *et al.*, 2004). Lambda cyhalothrin is highly toxic to mammals and is a known irritant. It is also highly toxic to fish, aquatic invertebrates and honey bees (Naravaneni & Jamil, 2005).



Structure of cyhalothrin

2.5.4 Plasticizers

Bis (2-ethylhexyl) phthalate an example of a plasticizer is an organic compound with the formula C_6H_4 $(C_8H_{17}COO)_2$. It is the most common member of the class of phthalates which are used as plasticizers (Meek & Chan, 1994). It is the diester of phthalic acid and the branched-chain 2-ethylhexanol. This colourless viscous liquid is soluble in oil, but not in water. Accounting for an almost 54% market share in 2010, DEHP is a High Production Volume Chemical (Koch *et al.*, 2006).



Bis (2-ethylhexyl) phthalate

The monitoring of the pesticide residues is very important in maintaining the quality of borehole water. Since wide range of compounds is used as pesticides then a variety of methods should also be involved in their analysis (Pramer & Bartha, 1972). The residue analysis involves the following steps; - extraction from the sample matrix, removal of interfering co-extractives, identification and estimation and confirmation of presence and identification.

2.6 Physico-chemical parameters

The parameters include; colour, turbidity, pH, BOD, sulphate and nitrates are discussed below.

2.6.1 pH

pH is a scale showing the intensity of both acidity and alkalinity of water and it measures the concentration of hydrogen ions. Most of the biological processes and biochemical reactions depend on the pH (Hiremath *et al.*, 2011). The measure of pH in drinking water is not a health concern, but acidic water can leach metals used in plumbing and this can cause health problems. High acidity in water may be due to excess CO_2 and SO_2 caused

by microbial activities and low pH values might be due to high levels of free CO_2 which may affect bacterial counts in drinking water (Anake *et al*., 2013).

2.6.2 Colour

Water should be transparent and clear and any change in colour indicates the presences of foreign material. Suspended materials and decaying organic matter and inorganic materials extracted from decaying vegetation, add colour and odour to the water (APHA 2002). Colour is commonly seen in surface water, while it is virtually absent in spring and deep boreholes due to material screening. Change in colour may also be as a result of natural metallic ions (iron and manganese) a yellow tint of water indicates that humic acids referred to as ‘tannins’ are present while a reddish colour would indicate the presence of iron precipitated. Stains on bathroom fixtures and on laundry are often associated with colour also reddish –brown is ferric hydroxide (iron) and it precipitate when the water is exposed to air. Dark brown to black stains are created by manganese and excess copper can create blue stains. The observed colour of water is as a result of light back scattered upwards from the water after it has passed through various depths and undergone selective absorption (Ombaka, 2012).

Colour and turbidity determines the depth to which light penetrates in water systems. The visible colour in a water sample is the light that is refracted, reflected, emitted or re-emitted by substances in water because it has not been absorbed to produce heat or chemical reactions. Colour measured in water containing suspended matter is defined as apparent colour (APHA, 2002). The colour of water measured by colometric methods is based on the calibration or absorbance of the water sample at a variety of single wavelengths, usually against the Pt-Co Standard measurement. Comparisons can be made

with sealed containers; Natural water range from less than 5 m/LPt in very clear water to 1200 mg/L in dark peaty waters (Keysre, 2007).

2.6.3 Turbidity

Turbidity is the term given to anything that is suspended in a water supply. It is most common in surface waters and usually non-existent in ground water except in shallow wells and springs after heavy rains. The suspended particles or colloidal matter prevents light transmission through the water (WHO, 2011). Sand, clay, silt, or suspended irons contribute to turbidity and it can cause decolourisation of sinks and fixtures as well as the discolouring of fabrics. Turbidity is measured and values given in NTU (nephelometric turbidity units) and drinking water have turbidity level of 0 to 1 NTU. Turbidity can also be measured in ppm (parts per million) and its size is measured in microns. Turbidity can also represent the optical property that causes light to be scattered and absorbed and rather transmitted in a straight line through the sample (Medudhula *et al.*, 2012).

A cyclone separator can reduce turbidity to 75 microns then reduced down to 20 microns with standard back washable filter, however flow rates of 5 gpm/sq. ft are recommended maximum. Turbidity can be reduced to 10 microns with a multimedia filter while providing flow rate of 15 gpm/sq. ft cartridge filter of various sizes are also available down into the submicron range (USEPA, 2007). The following are suspended matters that are known to cause turbidity and they include; clay, silts, finely divided organic and inorganic matter, soluble coloured organic compounds and plankton and other microscopic organisms. The optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample is expressed by turbidity. Correlation of turbidity with weight concentration of suspended matter is

difficult because the size, shape and refractive index of the particle also affect the light scattering properties of the suspension (Ombaka *et al*., 2012).

2.6.4 Biochemical Oxygen Demand (BOD)

The amount of organic matter present within a given water sample and its relative biodegradability of the organics may be estimated by analyzing samples of BOD. According to (Chapman 1993) BOD is an approximate measure of the amount of biochemically degradable organic matter in a sample. Clean water have BOD values of 2 mg/L O_2 or less whereas contaminated water may have values up to 10 mg/L O_2 or more especially near the point of waste discharge (Chapman,1993).

2.6.5 Nitrates

A high concentration of nitrogen in human excreta leads to water contamination by nitrates and they become a health hazard. It is used as an indicator of the rate of effluent infiltration through the soil and feacal contamination. Nitrates have been the most widely investigated chemical derived from pit latrines. When high concentration of nitrates is consumed in drinking water, it is known to cause methemoglobinemia a disease associated with cancer in humans. Ground water nitrate contamination is also caused by proximity to polluted sources, including pit latrines (Tandia, *2010*). According to WHO (2011), the recommended guideline for nitrate in drinking water is 50 mg/l.

2.6.6 Sulphates

Sulphates serve as one of the most essential nutrient which acts as a limiting factor when maintaining reservoirs fertility (Medudhula *et al.,* 2012). Sulphates do not have a health based guideline value. Sulphates dissolve in to the ground water as water moves through

the soil and rocks that contain sulphate minerals. According to (WHO, 2003) values higher than 250 mg/L should be reported to the health authorities because of its effects in the gastro-intestinal tract. Sulphates are found naturally in water as a result of leaching from gypsum and other common minerals (Manivaskam, 2005).

2.7 Research done on ground water in Kenya

A study was conducted in Narok north sub-county, Kenya to analyze physico-chemical properties of water in various water sources during the dry and the wet season to determine water quality for domestic use (Ndubi *et al*., 2015). Properties analyzed included pH, temperature, DO, BOD, TDS, TSS and total hardness. The results indicated that most parameters fell within the accepted range according to WHO except for the BOD which indicated the presence of microorganisms and hence the water is not fit for human use unless treated prior to consumption. Water pH, during the dry season, the highest mean pH value of 9.163 ± 0.050 was recorded in water tanks and the lowest pH mean value of 7.874 ± 0.008 was recorded in Nkareta River. When it came to dissolved oxygen, in the dry season, the highest DO mean value of 8.720 ± 0.194 mg/L was recorded in the water pans and the lowest DO mean value of 1.427 ± 0.108 mg/L was recorded in Ewaso Nyiro river in the dry season, the highest temperature of 26.013 ± 0.052 °C was recorded in Nkareta river and the lowest temperature of 22.913 ± 0.334 °C (Ndubi *et al*., 2015).

In addition another study was conducted to assess seasonal variation in physico-chemical and microbiological quality of groundwater in Ruiru, Kiambu County in Kenya. A total of 109 well water samples, 51 boreholes and 58 shallow wells during 2 different seasons, viz. dry and wet season were collected during the year 2015 and analyzed for

temperature, pH, colour, electrical conductivity, turbidity, total hardness, calcium, magnesium, Sulphate, nitrate, fluoride, iron, manganese, coliform count and Escherichia coli Significant difference between seasons was observed in all parameters studied except, for sodium and magnesium. The results were compared with WHO guidelines, 2009 and Kenya Bureau of Standards 2006 water guidelines to ascertain its suitability for domestic use (Makhoka, 2014).

Otieno *et al*., (2012) explained that the water quality is an index of health and is one of the areas of major concern to environmentalists, since industrialization, urbanization and modern agricultural practices have a direct impact on the water resources. Borehole water is the major source of water supply in Kihara division, Kiambu County. In this paper an attempt has been made to evaluate water quality parameters of selected boreholes. Chemical parameters which were analyzed are total alkalinity, chlorides, nitrates and heavy metals. Physical parameters like pH, Total Dissolved Solids (TDS), and turbidity were also analyzed and the results were compared with standard permissible limits by WHO. The results revealed that some of the parameters were above WHO standard for drinking water, so there is need for strict monitoring to ensure quality water supply for human health (Otieno *et al*., 2012).

A study was conducted to assess the water quality of Nyanchwa-Riana River flowing through Kisii town during the period May 2013 to June 2014 (Gichuki & Gichumbi, 2015). Sampling stations were selected on a transect covering the upper and middle reaches of Nyanchwa stream. A further two sampling stations were added after the confluence on the Riana River downstream. The water quality parameters assessed were dissolved oxygen concentration, pH, conductivity, turbidity, chlorophyll-a, total and

soluble phosphate and nitrate concentrations and coliform counts. Nutrient concentrations generally increased from the source of the Nyanchwa -Riana River towards the lower reaches the river. Soluble nutrient concentrations exhibited the same trend. The total phosphorous to total nitrogen ratio of 1:3 varied from the Redfield ratio of 1:16 commonly found in natural habitats. Observations on the physical and chemical parameters showed levels stressful to aquatic life, with dissolved oxygen concentrations less than 5 mg/L in some sampling points. These findings are useful in the management of the water quality in the two streams and on the River Riana flowing through Kisii town (Gichuki & Gichumbi, 2015).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1Reagents and Chemicals

Hexane, acetone, and anhydrous sodium sulfate (Na_2SO_4) were manufactured from Fisher Scientific Ltd. USA, Buffer solutions pH 4 and pH 7, magnesium chloride, sodium acetate, potassium nitrate, acetic acid, Barium chloride crystals, sodium salicylate, sodium hydroxide were purchased from Kobian Chemicals Ltd, Nairobi Kenya. The individual pesticide standards were greater than 99% pure and hence were used without purification. All the other solvents and chemicals were of analar grade and were used as received.

3.1.2 Equipment

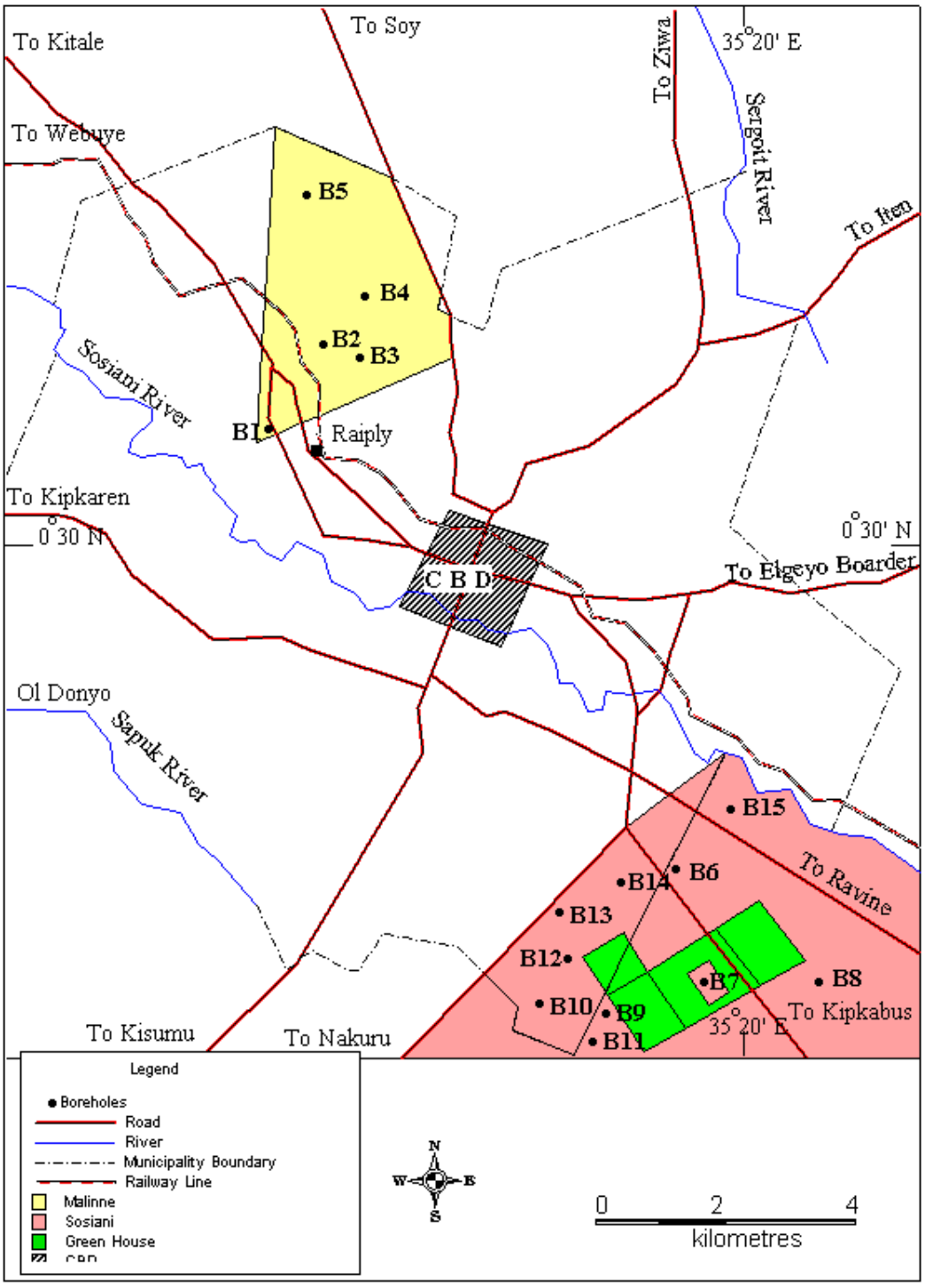
The following equipments were used for sample analysis; Shimadzu LC-2010 CHT HPLC system (Kyoto Japan), GC-MS (Hewlett Packard (HP) model 5977A, USA), UV/VIS (Shimadzu, Japan), PH Meter (mettler toledo model, Switzerland), Turbidmeter (eijkelkamp model, Holland), BOD meter (Oxitop model, Germany) and Lovibond apparatus.

3.1.3 Study Site

The study was carried out in Maili-nne and Sosiani areas of Eldoret, Uasin Gishu County. Eldoret town lies south of Cherangani Hills, the elevation varies from about 2100 m above sea level at the airport and more than 2700 m in nearby areas (700-9000 feet). It is

the fastest growing town in Kenya. The two sites lies between the latitudes 0° 3, and 00 and 55, N, and Longitudes 34° 50, E and 35° 37, E and it receives an average rainfall of 1124 per year. It has an average temperature of 18 °C during the dry season, with a maximum of 25 °C and minimum 9 °C during the cold season; it has a mean of 8.4 °C.

Maili-nne is one of the estates in Eldoret which is a residential for middle class community surrounded by industries and farming. Most of these industries discharge their liquid effluent into the municipality sewerage system while some are discharged on the surface which is carried away by rain water to various destinations. Sosiani area is an agricultural area driven by large scale grain farming, dairy farming and horticulture farming.


To Kitale
To Soy
To Ziwa
35°20' E
To Webuye
Sergoit River
To Iten
B5
B4
B2
B3
Sosiani River
B1
Raiply
To Kipkaren
0°30 N
0°30' N
C B D
To Elgeyo Boarder
Ol Donyo
Sapuk River
B15
To Ravine
B14
B6
B13
B12
B7
B8
B10
B9
B11
To Kipkabus
35°20' E
To Kisumu
To Nakuru
Legend
Boreholes
Road
River
Municipality Boundary
Railway Line
Malinne
Sosiani
Green House
N
W
E
S
0
2
4
kilometres

3.2 Methods

3.2.1 Sampling and sample processing

A total of 20 boreholes in Sosiani area and 12 boreholes in Maili-nne estate were identified as the main sources of water in the region. The study employed systematic sampling technique in which 10 boreholes at Sosiani farm and 5 boreholes in Maili-nne were selected for water sample collection which was appropriately coded. Samples were collected from the boreholes during dry season (January to April 2015) and wet season (May to November 2015) in triplicates. From each borehole, 1 litre of water was drawn into a sterile polythene container using a string notched on the clean container. After collection, water samples were kept in a cooler containing ice and transported to the government chemist laboratory within a period of 48 hours for analysis. In the laboratory, the samples were refrigerated awaiting analysis.

3.2.2 Organic Contaminants analysis

The water samples were first directly analysed with high performance liquid chromatography (HPLC) to determine presence of pesticides in form of organic compounds. Analysis for the organic contaminants was done according to the United states Environmental Protection Agency series 500 methodology. The pesticides residues under study included several types of organic semi-volatile compounds widely used in Africa as agrochemical that’s organophosphorous, organochlorines and pyrethroids.The pesticide classes are presented in Table 3.1. Stock standard solutions of individual compounds (1000 mg/L) for all compounds were prepared in dimethanol and stored at 4 °C in the dark. Working standard mixture solutions were prepared by appropriate dilution of the stock solutions in methanol.

Table 3.1: Selected organic compounds standard solutions retention time ranges

Compound class	Compound	Retention time range (min)
Organophosphorous	Diazinon	20 – 24
	Chlorpyrifos	10 – 13
	Fenitrothion	12 – 14
	Sulfotep	13 – 16
	Dimethoate	11 – 13
	Malathion	15 – 18
Organochlorides	Dieldrin	15 – 17
	Lindane	17 – 20
	Triallate	18 – 22
	Heptachlor	20 – 24
Pyrethroids	Bis (2-ethyl hexyl) phthalate	19 – 21
	Cyhalothrin	24 – 29

Confirmation data for comparing the retention time in the samples with the range of standard solutions (US EPA Series 500 methods Bulletin 865B)

HPLC analysis was carried out on a Shimadzu LC-2010 CHT HPLC system (Kyoto Japan). Chromatographic separation was performed on a Hedera™ ODS-2 RP-18 column (250 mm x 4.6 mm, 5 µm). The column was kept at 250 °C and the sample injection volume was 10 µL. The mobile phase comprised of (A) H_2O (acidified with 0.1% formic acid) and (B) MeOH:H_2O (90:10 v/v). Gradient elution was adopted with the organic solvent (MeOH:H_2O (90:10 v/v)) percentage changed linearly as: 0 min, 20%; 5 min, 20%; 10 min, 85%; 15 min, 90%; 20 min, 90%; 25 min, 20%; 30 min, 20%. Organophosphorous pesticide was detected without further cleanup using Nitrogen phosphorous detector. Further cleanup was done for organochlorine and pyrethroid and were then determined using electron capture detector. Mixed standard solutions of the pesticides classes organophosphates and organochlorides separately at concentration of 10 µg/mL were injected with volume of 10 µL. The chromatogram produced was

examined to identify the organic compounds detected in terms of retention times ranges referenced for the standards. The borehole water samples were similarly injected and retention times correlated to those of the standard solutions to identify the organic contaminants present.

3.2.3 Organic contaminants quantification

3.2.3.1 Preparation of calibration curves

To overcome matrix effect, calibration curves were prepared by the internal standard method using spiked samples of the selected pesticides. Ethylacetatic solution (1 mg/mL) of each standard and ethylacetatic solution of Triphenylmethane (TPM) (1 mg/mL) as internal standard were prepared and stored at -20 °C. Mixed standard solutions of the selected pesticides at concentration of 10 µg/mL were prepared in ethyl acetate. Then 10 mL of distilled deionized water was treated with a mixture of the pesticides to obtain 10 ng/g, 25 ng/g, 50 ng/g, 100 ng/g, 200 ng/g, 300 ng/g and 500 ng/g concentrations obtained by adding 10 µL, 25 µL, 50 µL, 100 µL, 200 µL, 300 µL and 500 µL of the standard mixture of pesticides respectively and concentrations of 10 µg/mL and 5 µL of the internal standard of the primary solution with the concentration of 1 mg/mL. The results of the analyzed samples were used for drawing the calibration curve. This process was repeated on three different days and finally, the calibration curve was drawn.

3.2.3.2 Sample extractions

Water samples were shaken well and filtered using Wattman filter paper no.1. After filtration exactly 50 mL of the sample was transferred into a 1 L separatory funnel and the mixture of 70 mL of hexane and acetone in the ratio of 1:3 was added to the sample and

shaken vigorously for 1 min before two phase separation. The contents were allowed to stand for 10 min and the aqueous layer then collected in another 1000 mL beaker. The procedure was repeated until all the water samples were extracted with the same 70 ml of hexane and acetone mixture. The aqueous phase was discarded and the organic phase collected in a beaker and then transferred to the water bath at 24.4 °C. The solution was brought to volume with hexane and acetone before passing through a syringe containing 0.5 g of anhydrous sodium sulfate (Na_2SO_4) directing it to the vials. The contents were mixed thoroughly then silylated and put in the oven at 60 °C for 30 min. The vials containing 4.5 µL volume of the sample was kept in a beaker and it was covered with parafilm before taken for analysis.

3.2.3.3 Sample analysis

The organic contaminants were determined and quantified with the aid of a gas chromatograph equipped with a mass –selective detector (GC-MS), with an auto sampler and a split- splitless injector separations on a HP-1 fused silica capillary column (12 m× 0.2 mm i.d.; 0.33 m film thickness). The carrier gas was helium (99.999% purity) at a flow rate of 10 mL /min. Oven temperature was maintained initially at 10 °C/min to 250 °C, then held at 250 °C for 24 min. Injection volume was 5 µl injected in a splitless mode at injection temperature of 250 °C. The mass spectrometer was operated in Electron impact (EI) ionization mode with a detector voltage of 70eV, ion source temperature of 250 °C, GC interfaced temperature of 280 °C. Acquisition mode was selected ion monitoring (SIM).

Samples were injected and run on the GC-MS under the set chromatographic conditions and the retention times compared with those of the standards. Identified pesticides were

additionally quantified using Mass spectrometer library in an interfaced data system used to obtain, store and output mass spectral data.

3.2.4 Physico-chemical parameters determination

Assessment of physico-chemical properties in water samples were obtained from all the sampled areas in triplicates during the dry and wet season, 45 samples were obtained put in a cooler and transported to the laboratory.

3.2.4.1 pH

The pH meter was calibrated using buffer solutions of pH 4 and pH 7. To determine the water sample pH, the meter probe was immersed into the sample and readings recorded in triplicates then mean calculated.

3.2.4.2 Biological Oxygen Demand (BOD)

The BOD was determined as the difference between the oxygen concentration before and after incubation for 5 days at 20 °C in the dark. The initial O_2 was read using HI9143 HANNA model DO meter. The solution were closed tightly so that it could not trap in any air bubbles and then incubated in the water bath in an inverted manner. The temperature was maintained at 20 °C. After 5 days and the readings of the final oxygen were recorded in triplicates and the mean calculated and recorded. The BOD was the difference between the initial and the final readings.

3.2.4.3 Colour

An aliquot of 50 mL of sample were transferred into a test tube used for colour analysis. The sample was placed into the right compartment of the lovibond apparatus and distilled water on the left. The colour disc was then rotated until a standard colour match was

found for the samples. The records of the readings in HU were done for all the samples in triplicate.

3.2.4.4 Turbidity

Turbidity was measured using turbidmeter as per APHA. This was done in triplicates and the mean value taken and recorded in a table.

3.2.4.5 Nitrate and sulphate nutrients

Analysis of the nutrients was done using a calibrated spectrometer at 420 nm. The blank consisted of distilled water sample prepared in a similar manner to standard solutions without adding the nutrients standards. Calibration curves were then generated using prepared standard solutions at concentration range from 0.1 µL to 1.0 µL. Sulphate ion was precipitated in acetic acid medium with Barium chloride ($BaCl_2$) to form Barium sulphate ($BaSO_4$) crystals of uniform size. Light absorbance of the $BaSO_4$ was measured at 420 nm. Nitrate ions and sodium salicylate reacts in an alkaline medium for a yellow sodium nitrosalicylate which was determined at 420 nm. The absorbances for the borehole water samples were then determined and correlated to the calibration curves to establish the nitrates and sulphates content.

3.3 Data Analysis

In the study, the physico-chemical properties and level of organic contaminants of the water samples was determined and to find out if there was a significant deviation of the mean samples from the acceptable level, one sample t test was done and the critical alpha adopted during the study was 0.05. To compare if there was a significant difference in physico-chemical properties of the samples between two sites of interest an independent samples t test was used to determine if there was homogeneity of variance in means during the study. To compare if there was a significant difference between physico-chemical properties during the dry and the wet season, paired sample t test was used to compare means of the same boreholes during the two seasons. Correlation analysis was used to determine if there was a significant relationship between organic contaminants and physico-chemical properties of borehole water.

CHAPTER FOUR

4.0 RESULTS AND DISCUSION

The results of organic contaminants (diazinon, chloropyrifos, cyhalothrin, bis(2-ethylhexyl) Phthalate, dieldrin, lindane, fenitrothion, heptachlor, dimethoate and malathion); physico-chemical parameters (BOD, pH, turbidity, colour, nitrates and sulphates) tested in the water samples from the sampled boreholes in Eldoret region are presented in this chapter. Detailed discussions are also made in relation to the findings of this study and findings of other related studies done in other locations worldwide.

4.1. Sampling

Sampling was done in 15 boreholes, five in Maili-nne and ten in Sosiani. The samples were coded MB1-MB5 for Maili-nne and SB6-SB15 for Sosiani and were represented as shown in table 4.1 below.

Table 4.1 Maili-nne samples

Borehole	Sample coding
1	MB1
2	MB2
3	MB3
4	MB4
5	MB5

Table 4.2 Sosiani samples

Borehole	Sample coding
1	SB6

2	SB7
3	SB8
4	SB9
5	SB10
6	SB11
7	SB12
8	SB13
9	SB14
10	SB15

4.2 Organic contaminants detection

HPLC chromatograms was appropriately obtained for the organophosphates (Fig 4.1) and Organochlorines (Fig 4.2) which confirmed the presence of organic compounds on correlation of the retention times to the standards retention time ranges.

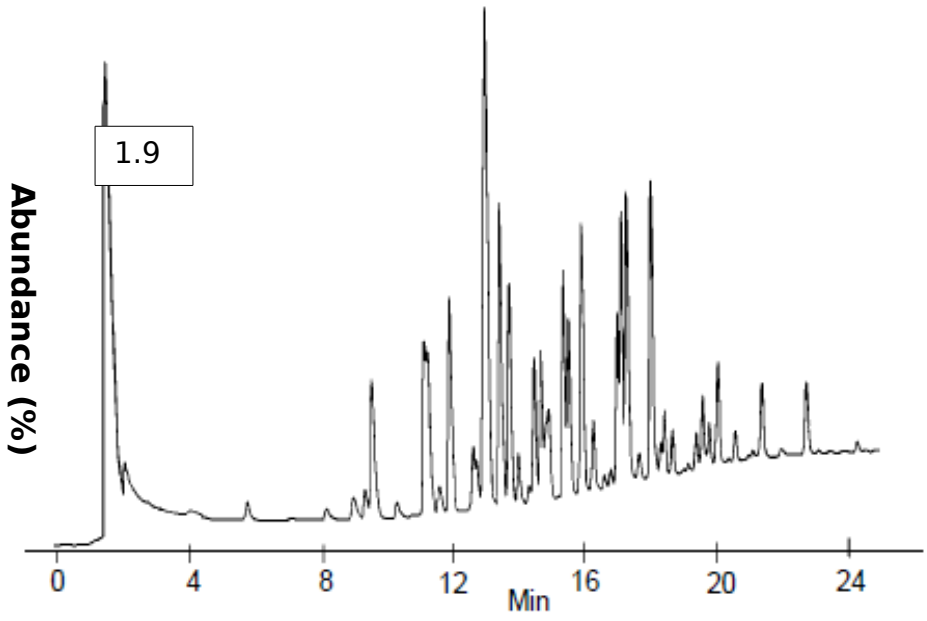


Figure 4.1: Chromatograph for organophosphates detection in the water samples showing peaks retention time 8 – 24 minutes (US EPA series 500 methods 865B)

The organophosphates were identified to have been eluted as per the following respective times; Diazinon, chloropyrifos, fenitrothion, sulfotep, dimethoate and malathion at 23, 10, 12, 16, 13 and 18 minutes, respectively. The peak at retention time 1.9 represents the solvent ethyl acetate.

Similarly, the organochlorines and pyrethroids were noted to elute at respective times as dieldrin, lindane, triallate, heptachlor, bis (2-ethylhexyl) phthalate and cyhalothrin at 15, 18, 19, 20, 21 and 28, respectively.

Appropriate matching of the retention time designation, additionally confirmed in respect to the peak heights that corresponded to the concentrations of the standards prepared.

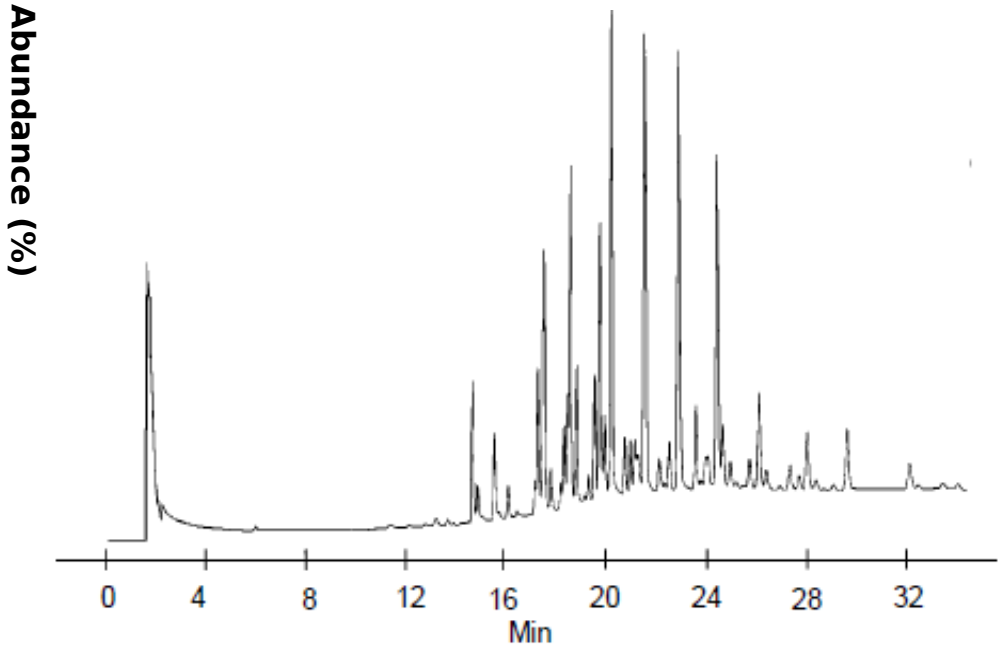


Figure 4.2: Chromatogram for the organochlorines and pyrethroids detection in the sample showing peaks retention time 15 – 32 minutes (US EPA series 500 methods 865B)

4.3 Organic contaminants quantification

Quantification of the detected organic compounds was carried out by GC-MS. The amounts of each identified pesticide residue were individually assayed in the boreholes for the dry and the wet season, and the levels found to take the following discussed trends.

4.3.1 Organophosphates

4.3.1.1 Diazinon

Diazinon which is considered to be highly toxic for vertebrates mainly because of its action as an acetylcholinesterase (AChE) inhibitor once ingested (Wismer & Means, 2012), was present in some of the boreholes at varying concentrations as outlined in table 4.3

Table 4.3 Average diazinon concentration in boreholes 9, 12 and 13

Borehole	**Average Diazinon Concentration**	
	Dry Season (mg/L) Mean +standard deviation	**Wet Season (mg/L)**
SB9	0.35±0.09	0.20±0.04
SB12	0.00	1.52±1.01

SB13	2.21±0.12	0.00

Analysis of the water samples revealed that there exist residues of diazinon in the boreholes SB9, SB12 and SB13. All these boreholes are in Sosiani farm. During the dry season, the highest mean value was 2.33 mg/L (SB13) and the lowest mean value was 0.00 (SB12), while during the wet season the highest mean was 1.52 mg/L (SB12) and the lowest mean was 0. 00 (SB13).

These findings apparently showed that there is an intense use of diazinon by the farmers around the three boreholes and through either irrigation surface runoff or rain surface runoff, this organic contaminant was carried or percolated into the three boreholes. In borehole SB12 during dry season, diazinon was not detected because there was no activity going on in the green house located near this borehole at the time of sample collection and these also apply to borehole SB13.

The present study concur with a study done by Michel (2012) to analyze underground water in 2010 on five borehole water samples situated in agricultural cotton zone. The obtained results showed the presence of various active matters of at least 76 residues of pesticides, especially insecticides, herbicides and fungicides, with accumulated contents which could average 0.350 or 350 µg/L per borehole. Indeed, all the prospected boreholes were contaminated.

4.3.1.2 Fenitrothion

From the results it was evident that there were residues of fenitrothion in borehole MB1 during the dry and the wet seasons at mean levels of 0.145 and 0.191 mg/L, respectively.

It could be deduced that the probable source was insecticides used to control pests. The concentration of residue fenitrothion in samples from borehole 1 was 0.145 ppm for the dry season and 0.191 ppm for the wet season. These values were below Maximum Residue Limit (MRL) set by EPA of 0.25 mg/L for fenitrothion in drinking water (FAO, 2013; Maštovská & Lehotay, 2004). This may be attributed to the fact that fenitrothion is non-systemic and non-persistent in the environment (Thomas, Wood & Solorzano, 1999). The results are in line with those of a study done by Essumang, Togoh & Chokky (2009) who assessed the concentration of pesticide residues in the water in Cape Coast, Ghana. Their results showed that the concentration of fenitrothion in the water was 0.0148 mg/L which was far less than the set MPL.

4.3.1.3 Chloropyrifos

This was found to be present in the two areas of study as indicated in Table 4.4**.**

Table 4.4 Average chloropyrifos concentration in boreholes 1, 9, and 13

Borehole No.	**Average Chloropyrifos Concentration**	
	Dry Season (mg/L)	**Wet Season (mg/L)**
	mean ± standarddeviation	
MB1	0.129±1.02	0.000
SB9	0.101±0.01	0.000
SB13	0.362±0.94	0.000

Table 4.4 presents the findings of chloropyrifos organic contaminant in the borehole number MB1, SB9 and SB13 for the dry season. It was found that there were residues of chloropyrifos in the borehole number MB1, SB9 and SB13 only during the dry season at the mean levels 0.129 ppm, 0.101 ppm and 0.362 ppm, respectively. Chloropyrifos was not detectable in the samples collected during the wet season and this could be due to the fact that chloropyrifos is strongly absorbed by soil and does not readily leach from it but degrades there through microbial action (Sparks, 2003).

During the study, Maili-nne estate was chosen for the study because there was no agricultural activities taking place and the chances of the organic contaminant in the boreholes in this area was thought to be absolutely impossible, however in borehole number MB1 there was a residue of chloropyrifos suggesting that the proximity of the borehole to where the contaminants are is not a criteria for the possibility of contamination. Nonetheless, the contamination by chloropyrifos could have been by chance whereas in borehole number SB9 and SB13 the contamination was due to the use of the organic compound as a pesticide in the farm.

Chloropyrifos, also known as Dursban, is one of the most commonly used insecticides on corn crops. It is also used to control pests on cattle, and it is widely used around the home for control of cockroaches, fleas, and termites. Chloropyrifos does not mix well with water and sticks tightly to soil particles. It was detected in trace amounts in a small percentage in private water systems among them boreholes. Chloropyrifos is presently considered a possible human carcinogen. No drinking water standard exists for chloropyrifos. Environmental Protection Agency recommends that children should not drink water containing levels greater than 0.03 mg/L (Kristen, 2012). Therefore the

present study suspects that the presence of the contaminant in the borehole MB1 was due to the use of the compound in killing domestic pests like cockroaches. While in borehole number SB9 and SB13 could have been due to the widespread use of the chloropyrifos as pesticide control in Sosiani farm.

4.3.1.4 Malathion

Malathion was only detected in Sosiani farm area but not in Maili-nne and only during the dry season specifically in boreholes SB6 and SB15 at mean levels of 0.207 mg/L and 0.94 mg/L, respectively. It was not detected during the wet season mostly due to its chemical characteristic whereby it is easily converted in the presence of water from malathion to malaoxon (Bonner *et al.*, 2007).

4.3.1.5 Sulfotep

Sulfotep being an aerosol in nature is mostly distributed in air during its use as a fumigant rather than being dissolved in water hence the minimal concentration in underground water. Sulfotep was at quite minimal levels than the other organic contaminants in all boreholes during both the dry and the wet seasons. Sulfotep was only detected during dry season in water samples obtained from SB9 and SB13. These two boreholes are located in Sosiani farm where the use of pesticides and herbicides is rampant. The concentration of residue sulfotep in samples from SB9 and SB13 was 0.01 ppm and 0.03 ppm, respectively.

These values were below Maximum Allowable Concentration (MAC) of 0.1 mg/L for sulfotep in drinking water (WHO, 2004). These results were slightly higher than those

reported by Elegbed *et al.* (2013), who reported values of 0.07 µg/L in drinking water in Kérou, Benin. Greulich & Alder (2008) also reported low values of 0.018 µg/L in ground water in Merck, Germany. However, US EPA (1998) reported high values of sulfotep in surface waters, with the majority of results being above 0.1 ppm in various locations in USA.

4.3.1.6 Dimethoate

Dimethoate was only detected in water samples from SB7 only during the wet season. The concentration of residue dimethoate in samples from SB7 was 0.86 ppm. This value was above Maximum Allowable Concentration (MAC) of 0.03 mg/L for dimethoate in drinking water (WHO, 2004). This organic contaminant could have been carried into the borehole via surface runoff during rainy season because the borehole is located around Sosiani farm.

These results were in line with those of Starner *et al.* (2005) who reported values of 0.696 µg/L in drinking water in California, USA. Siepmann & Holm (2000) also reported high values of 0.36 µg/L in Sacramento-San Joaquin River System in USA. Figure 4.3 illustrates the summary of existence of organophosphates in the boreholes.

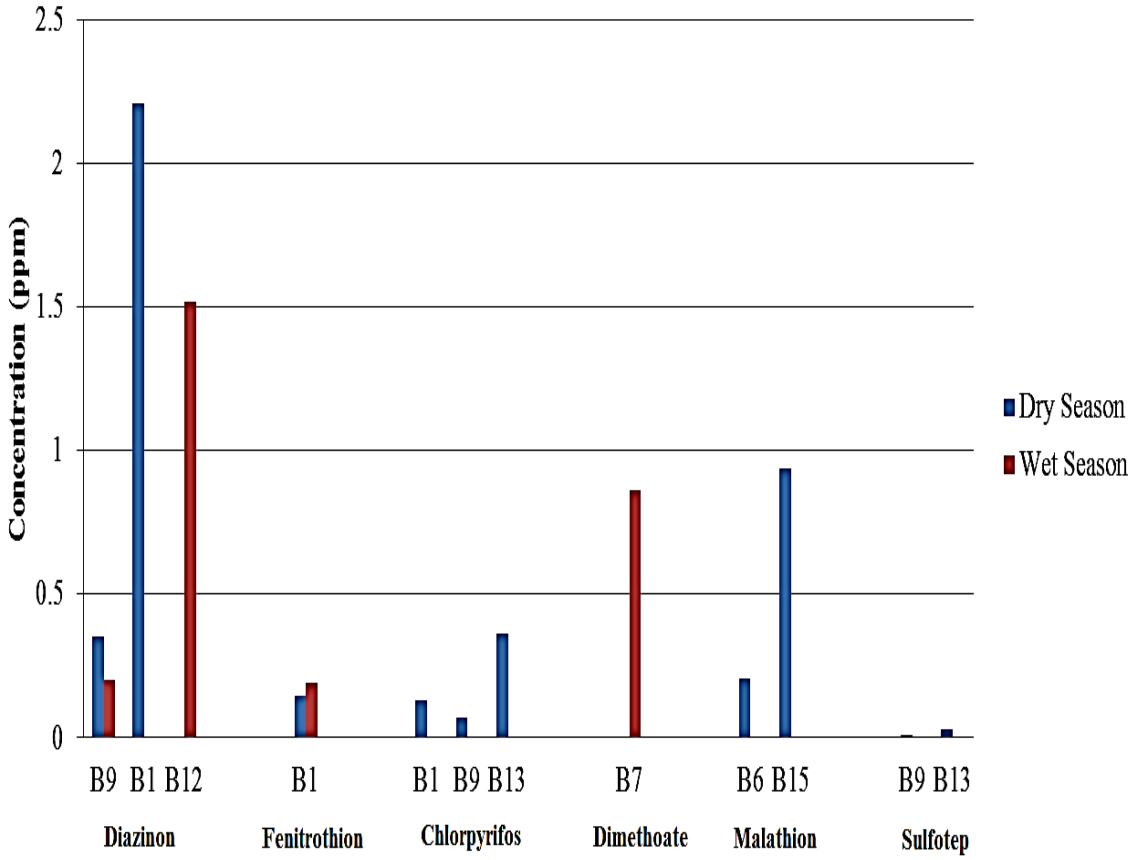


Fig 4.3: Distribution of the six organophosphates in the borehole water samples

In summary, the organophosphates were detected in various boreholes both in Maili-nne and Sosiani areas. This is because several of them may arise from residues of chemicals sprayed in residential areas for insect control and those used in the farm as pesticides.

4.3.2 Organochlorines

The organochlorine pesticide residues were detected in the boreholes at both Maili-nne and Sosiani farm area during the wet season but not the dry season as shown in figure 4.4. This could be a contribution of the chlorides having been broken down more during the dry season by free radical reaction processes orchestrated by intensive UV light during the season as compared to the wet season (IPCS, 1992). High wash over by

surface runoff might also have led to high levels of the organochlorides in ground water during the wet season. The various levels of the individual organic compounds of the class were established to be as follows:

4.3.2.1 Dieldrin

Dieldrin was only detected in water samples from MB2 in the wet season. The concentration of residue dieldrin in samples from borehole MB2 was 0.29 ppm. This borehole is not located in an agricultural farm but in a residential area. This value was above Maximum Residue Limit (MRL) of 0.03 µg/L for dieldrin in drinking water (WHO, 2013). The possible reason as to why this particular borehole was contaminated is that it might not have been protected from direct surface runoff during the rainy season or the contaminant could have been delivered to the borehole by un-informed individual. The high concentration of dieldrin in borehole MB2 may also be attributed to the high usage of dieldrin-containing pesticides in the agricultural fields around this borehole in Maili-nne.

4.3.2.2 Lindane

Lindane was only detected in water samples from MB3 in the wet season. The concentration of residue lindane in samples from MB3 was 1.29 ppm. This value was above Maximum Residue Limit (MRL) of 0.3 µg/L for lindane in drinking water (WHO, 2004). Lindane is highly volatile and when applied to the field 90% enters the atmosphere and later deposited by rain. Lindane is also leached into surface waters and even into ground water (Drinking Water, 1993).

4.3.2.3 Heptachlor

From the results, it was evident that residues of heptachlor in the borehole MB5 during the wet season amounted to a concentration of 1.37 ppm. This borehole is located in Maili-nne estate, due the fact that insecticides are used in homesteads, there was chance of the contaminant being carried by runoff during the wet season.

4.3.2.4 Triallate

The concentration of residue triallate in the samples was quite low and detected only in SB13 at 0.02 ppm. This value was below Maximum Allowable Concentration (MAC) of 0.1 mg/L for triallate in drinking water (WHO, 2004).

Figure 4.4 outlines the summary of average concentrations of the organochlorines in Maili-nne and Sosiani farm boreholes

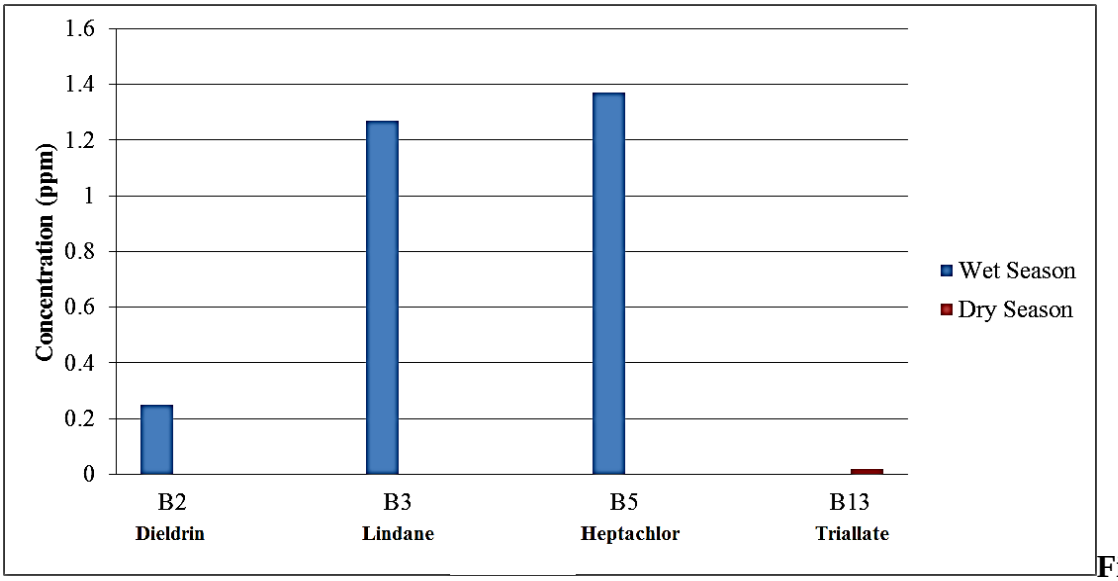


Figure 4.4: Comparison of concentrations of the organochlorines in the borehole water samples

4.3.3 Pyrethroids and Phthalates

The pyrethroid found in the study area was cyhalothrin and the concentrations of various boreholes are shown in table 4.5.

4.3.3.1 Cyhalothrin

Table 4.5: Average Cyhalothrin Concentration in borehole 1, 6, 7 and 9

Borehole No.	**Average Cyhalothrin Concentration**	
	Dry Season (mg/L)	**Wet Season (mg/L)**
	mean ± standard deviation	
MB1	0.11±0.09	0.00
SB6	0.00	1.37±1.31
SB7	1.25±1.03	0.00
SB9	1.47±1.06	1.21±1.03

This study shows that there existed residues of cyhalothrin in boreholes MB1, SB6, SB7 and SB9 found in both Maili-nne and Sosiani farm areas. The quantities of residue cyhalothrin in samples from borehole MB1, SB7 and SB9 in the dry season had mean value of 0.11, 1.25 and 1.47 ppm, respectively. During the wet season, the quantities of residue cyhalothrin in samples from borehole SB6 and SB9 had mean of 1.37 and 1.21 ppm, respectively. Borehole MB1 is found in Maili-nne estate in an enclosed area free from any physical health hazard. Surprisingly, borehole MB1 in Maili-nne estate was contaminated with insecticide cyhalothrin. This indicates that the borehole is receiving contaminants directly from the homesteads within the estate or there could be a nearby small garden that its pesticides are carried during rainy season to the borehole. Boreholes

number SB6 and SB9 are located in a farm and due to the use of the pesticide in the farm surface runoff or improper use of the pesticide could have caused the contamination of the boreholes.

The present finding is in agreement with a study that was done about organophosphate and pyrethroid insecticide residue levels in water bodies in cotton growing areas in Savelugu/Nanton District in the northern region of Ghana. Water samples were collected from twelve boreholes and four hand-dug-out wells from sixteen communities in the district and analyzed using the US EPA Method 3510 for aqueous matrix for the analysis of semi-volatile and non-volatile organics. In total, eight different insecticides were detected. Concentrations of cyhalothrin, chloropyriphos and flubendiamide in the water samples were 0.910, 0.870 and 0.621 µg/L, respectively and were higher than the maximum residue limit of 0.5 µg/L (Aliyu, 2015).

4.3.3.2 Phthalates

Phthalates were found in all the 15 boreholes and the results are shown in table 4.6.

Table 4.6: Average concentration of bis (2-ethylhexyl) phthalate in the 15 boreholes

Borehole	**Concentration (µg/L)**
Maili-nne	**Mean ± standard Deviation**
MB1	0.023±0.011
MB2	0.019±0.036
MB3	0.013±0.042
MB4	0.083±0.028
MB5	0.106±0.051
Sosiani farm	
SB6	0.172±0.115
SB7	0.097±0.04
SB8	0.054±0.003
SB9	0.098±0.041
SB10	0.021±0.036
SB11	0.030±0.027
SB12	0.000±0.057
SB13	0.030±0.027
SB14	0.004±0.053
SB15	0.067±0.01

The concentration of bis (2-ethylhexyl) phthalate in the 15 boreholes ranged from 0.021 µg/L (SB12) to 0.172 µg/L (SB6). The mean concentration of bis (2-ethylhexyl) phthalate in the boreholes from Maili-nne region was 0.67 ppm while the mean concentration for boreholes in Sosiani region was 0.59 ppm. Phthalate was found in the 15 boreholes attributed to the fact that phthalates are a class of multifunctional chemicals used in a

variety of consumer and personal care products. High molecular weight phthalates are primarily used as plasticizers in the manufacture of flexible vinyl, which is used in consumer products, flooring, wall covering, food contact applications and medical devises (Hauser *et al.,* 2006)

One sample t - test shows that the level of bis (2-ethylhexyl) phthalate in Maili-nne is not statistically significantly different from the mean standard value of 0.006 ug/L, $p=0.05<0.088$. While in Sosiani farm, the level of bis (2-ethylhexyl) phthalate was significantly different from mean standard value, $p=0.05<0.014$. This is the hypothesis of the present study. Because intensive farming and use of pesticide was taking place in Sosiani farm, the chance of the pesticide getting into some boreholes was high, hence through surface runoff or irrigation overflow via aerosols into the uncovered boreholes.

4.4 Statistical Data Analysis and Interpretation of Physico-chemical Parameters

The results of the physico-chemical parameters (pH, colour, turbidity, BOD, nitrates and sulphates) and organic contaminants (organophosphates, organochlorines, pyrethroids and phthalates) were subjected to one sample t-test, paired sample t-test, independent sample t-test and correlation analysis. The results and interpretation are as shown below.

4.4.1 pH

The pH is a measure of the effective concentration of hydrogen ions and is usually expressed on a scale that ranges from 0-14 units. It is a scale of intensity of acidity and alkality of water and measures (Hiremath *et al.*, 2011).

The mean pH values shown in Table 4.7 comprises of the value of pH of water samples during the dry and the wet seasons, pH values of the water samples from Maili-nne (MB1-MB5) and from Sosiani (SB6-SB15). Furthermore, the table shows that the pH of the sampled borehole water from Maili-nne during dry season had mean value ranged between 5.45-5.92 in borehole labeled number MB4 and MB2, respectively. During the same season, in Sosiani farm, the pH mean value ranged between 5.63 and 6.64 in SB10 and SB15, respectively. During wet season, water samples obtained from Maili-nne estate had pH mean value range between 5.73 (MB4) and 6.26 (MB2) whereas samples from Sosiani farm, the pH mean value ranged between 5.99 and 6.30 in borehole SB7 and SB14, respectively.

Table 4.7: pH levels of water samples

	Average pH Value Mean±Standard deviaton	
Borehole number	**Dry Season**	**Wet Season**
Maili-nne		
MB1	5.76±0.10	6.23±0.04
MB2	5.92±0.14	6.26±0.04
MB3	5.66±0.11	6.11±0.02
MB4	5.45±0.13	5.88±0.04
MB5	5.69±0.11	5.73±0.04
Sosiani		
SB6	5.84±0.11	6.11±0.02
SB7	5.87±0.12	5.99±0.03
SB8	5.68±0.15	6.19±0.02
SB9	5.75±0.12	6.09±0.02
SB10	5.63±0.12	6.09±0.03
SB11	5.79±0.12	6.08±0.03
SB12	5.68±0.12	6.08±0.03
SB13	6.62±0.11	5.99±0.04
SB14	6.61±0.01	6.30±0.03
SB15	6.64±0.12	6.16±0.03

The values of pH from the 15 boreholes were statistically analysed and the results are as shown in table 4.8.

Table 4.8 pH one sample t test

Test value=pH 6.5
Standard deviation
0.17038
0.2297
0.42891
0.09211

Table 4.8 shows analysis of pH levels of the water using one sample t test, two tailed distribution. The analysis of pH for the water samples in Maili-nne and Sosiani farm using one sample t test (Table 4.8) shows that pH levels of the water varied significantly from the set value. The test value used was 6.5, the lowest level of pH for water used domestically (WHO, 2004). Conversely, the data analysis output shows that during the dry season (p=0.00) and

the wet season (p=0.011) for the samples obtained in Maili-nne, the pH was significantly different from the acceptable standard value of 6.5 at $\propto = 5\%$ level of significant. Similarly, samples from Sosiani farm, during the dry season (p=0.006) and the wet season (p=0.00) were significantly different from the test value. These findings indicate that in respective seasons the water pH is lower than the acceptable standard and may cause some health concerns related to low pH. This means that water from the boreholes in Maili-nne and Sosiani may not be safe for direct human consumption.

Table 4.9: pH Paired Sample t Test

Site	P value	Std deviation
Maili-nne	0.012	0.170
Sosiani	0.478	0.415

Table 4.9 shows a paired sample t test to find out if there is a significant difference in pH level in Maili-nne between the dry and the wet season. The table shows that pH values between the dry season and the wet season in Maili-nne estate significantly differ (p value 0.012) while in Sosiani farm, the pH of the water samples do not differ significantly during dry and wet season, p=0.478.

This means that in Maili-nne, the contamination that causes significant change in pH occurs during the wet season. This could be due to surface runoff during heavy rains that wash contaminants into the boreholes. The pH of the water resources is acidic in nature with pH values < 5.50 at all seasons. A study by Efe (2000) explained that maxima and minima concentrations of the priority physico-chemical water quality parameters

examined in the borehole water resources were either above or below the target water quality range for domestic use, making three water resources available in the area a potential health hazards to inhabitant.

Correspondingly, there was no significant difference in pH level between the two sites during the wet season. This shows the pH level in Maili-nne and Sosiani remain relatively the same during all time of the year in both sites. These findings point out the possible sources of substances that lower the pH of the borehole water in Sosiani and Maili-nne. In Maili-nne, the activities going on there include only washing of clothes and utensils while in Sosiani, a number of farming activities that involve the use of herbicides and pesticides takes place. But there was no significant difference in pH during dry season as well the wet season in pH of the water samples obtained from the two sites. There could be a possibility that the chemistry of the bedrock could be the one that influences the pH since the two areas reside on the same bedrock, or the activities that take place in the estate that involve the use of detergents could have altered the pH of the water samples obtained in Maili-nne such that, there was no significant difference between in pH between the two water samples from different sites. Ocheri (2014) also found similar results in his study that borehole water samples obtained in Nigerian boreholes had a pH mean of 7.55 and 6.21 for wet season as against 8.26 and 4.24 for dry season. However, the result of the borehole samples pH analysis show acidic characters.

In addition Otieno *et al*. (2012) explained that chemical parameters which were analyzed in Kiambu were total alkalinity, chlorides, nitrates and heavy metals. Physical parameters like pH and turbidity were also analyzed and the results were compared with standard permissible limits set by WHO. The results revealed that some of the parameters were

above WHO standard for drinking water, so there is need for strict monitoring to ensure quality water supply for human health.

Table 4.10: pH Independent sample test

	Leven's test of equality	
Season	**Variance**	**P value**
Dry season	0.015	0.640
Wet season	0.007	0.565

The present study sought to find out if there was a significant difference in the level of pH in water samples based on the season and site (Table 4.10). When pH values for the samples obtained in Maili-nne and Sosiani farm acquired during dry season was compared to determine if there was a significant difference in the two sites, the output showed that there was no significant difference in pH between the two sites, p=0.64. Correspondingly, there was no significant difference in pH level between the two sites during wet season, p=0.57.

4.4.2 Turbidity

Turbidity in water is because of suspended solids and colloidal matter. It may be due to eroded soil caused by dredging or due to the growth of micro-organisms.

Table 4.11: Turbidity level of the sampled water

	Average Turbidity mean ± standard deviation	
Borehole number	**Dry Season (NTU)**	**Wet Season (NTU)**
Mailli-nne		
MB1	1.23±0.44	1.32±0.53
MB2	3.39±0.43	2.60±0.54
MB3	3.84±0.44	3.08±0.56
MB4	6.42±0.46	2.75±0.58
MB5	2.94±0.43	1.51±0.61
Sosiani		
SB6	1.61±0.45	2.09±0.62
SB7	3.81±0.44	0.87±0.64
SB8	2.28±0.47	5.48±0.61
SB9	4.62±0.48	5.49±0.64
SB10	2.71±0.52	4.84±0.68
SB11	3.11±0.56	2.54±0.74
SB12	4.71±0.63	2.83±0.84
SB13	7.24±0.77	1.85±1.01
SB14	3.42±0.37	8.42±1.28
SB15	1.39±0.24	1.43±0.91

Table 4.11 shows the results for turbidity levels of the water samples obtained from the two sites. During the dry season the turbidity mean values ranged between 1.23 NTU-6.42 NTU and 1.32 NTU- 3.08 NTU during the wet season in Maili-nne estate. However, in Sosiani farm, the turbidity mean ranged between 1.39 NTU and 7.24 NTU during the

dry season whereas during the wet season the mean ranged between 1.43 NTU and 5.49 NTU. Turbidity being a measure of clarity in water is a key test of water quality. The values obtained from the 15 boreholes were subjected to analysis and the following results were obtained.

Table 4.12: Turbidity One sample t test

	Test value 5 NTU			
Site	**P value**	**N**	**Mean NTU**	**Std. Deviation**
Maili-nne				
Dry season	0.016	5	3.5640	1.87751
Wet season	0.001	5	2.2520	0.78643
Sosiani				
Dry season	0.022	10	3.4900	1.73514
Wet season	0.093	10	3.5840	2.38269

Table 4.12 shows one sample t test to ascertain if there was a significant difference deviation of the turbidity from the standard value of 5 NTU. Water turbidity above 5 NTU is not fit for human consumption. From the table it is evident that samples from Maili-nne during dry (p=0.016) season and wet season (p=0.001) was statistically significantly different than the test value of 5 NTU likewise in Sosiani farm the turbidity

of water was significantly different than 5 NTU (p value 0.022) during the dry season and not statistically different (p=0.093) during the wet season.

These findings suggest that the turbidity of the water samples are below the required standard and is safe for human consumption if turbidity alone was to be considered. A varying finding was demonstrated by Amankona (2013) who proved that there was a general increase in all the physico-chemical parameters during wet season with turbidity, conductivity and total dissolved solids recording high values. The study further stated that during wet season the variation in turbidity goes beyond the required standard of 5 NTU.

Table 4.13: Turbidity paired sample t test

Site	P value	Mean	Std deviation
Maili-nne	0.109	3.564	1.878
Sosiani	0.924	3.490	1.735

Table 4.13, shows paired t test result. The output shows that in Maili-nne the p value is 0.109 meaning that there was no significant difference in turbidity of the water samples during the dry and the wet seasons. Likewise, in Sosiani farm, the turbidity level of the water samples do not differ significantly (p=0.924) during the dry and the wet seasons.

Factors that influence the level of significance of the borehole water samples did not influence the turbidity in the dry and the wet seasons. Hence the turbidity remained constant (p=0.05<0.109) and (p=0.05<0.924) during seasons across the year.

Table 4.14: Turbidity independent samples test on turbidity

	Leven's test of

	equality	
Season	**Variance**	**P value**
Dry Season	0.961	0.941
Wet season	0.280	0.135

Independent sample t test in Table 4.14 compares the mean of turbidity during dry and wet season between two sites of the study. When the mean turbidity of the water samples acquired during the dry season from Maili-nne and Sosiani farm was compared, the findings showed that there was no significant difference (p=0.941) in turbidity between the two sites. Moreover, during the wet season, the turbidity of the water samples from Maili-nne estate and Sosiani farm did not differ significantly (p=0.135).

Although the turbidity remained constant, an independent sample t test compares the mean of the turbidity during the dry and the wet season between two sites of the study. This shows that despite the activities taking place in Sosiani and Maili-nne, these do not influence their turbidity of the water in the borehole of the two sites. This is an indicator that substances that cause a change in borehole water turbidity in Maili-nne and Sosiani do not find their way into the boreholes either during the dry or the wet seasons. This means that all the boreholes are closed and well constructed to prevent surface runoff into the boreholes in the two sites of the study.

Turbidity is the term given to anything that is suspended in a water supply. It is most common in surface waters and usually non-existent in ground water except in shallow wells and springs after heavy rains. Turbidity gives the water a cloudy appearance or shows as dirty sediments. Undissolved materials such as sand, clay, silt or suspended

irons contribute to turbidity (Ucheri, 2014). During the study, the current research also aimed at finding out the level of contamination of the borehole water as indicated by the turbidity of the sampled borehole water.

4.4.3 Colour

Variation in colour in water may be caused by the presence of minerals such as iron and manganese or by substances of vegetable origin such as algae and weeds. Colour tests indicate the efficacy of the water treatment system.

Table 4.15: HU colour values of the water samples from the 15 sampled boreholes

	Average Colour Value Mean ± Standard deviation Dry Season (HU)	Wet Season (HU)
MB1	10±3.09	10±3.48
MB2	70±3.15	10±3.56
MB3	125±3.24	40±3.65
MB4	150±2.89	10±3.80
MB5	010±1.64	10±3.90
SB6	10±1.70	10±4.00
SB7	10±1.76	10±4.10
SB8	10±1.83	10±4.17
SB9	30±1.90	150±4.20
SB10	10±2.08	40±3.90
SB11	40±2.19	10±4.28
SB12	30±2.52	160±4.32
SB13	90±3.08	100±3.01
SB14	10±1.76	50±1.89
SB15	10±1.78	10±4.15

During the dry season, the results in Table 4.15 shows that the colour concentration of the water from the sampled boreholes ranged between 10 HU to 150 HU while during the wet season, the concentration ranged between 10 HU and 160HU.

Table 4.16: One sample t test Colour

	Test Value = 15HU					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Dry season Maili-nne	2.014	4	.114	58.000	-21.940	137.940
Wet season Maili-nne	.167	4	.876	1.000	-15.659	17.659
Dry season Sosiani	1.240	9	.246	10.000	-8.238	28.238
Wet season Sosiani	2.107	9	.064	40.000	-2.955	82.955

Table 4.16 shows one sample t test analysis for the colour values of water samples obtained in Maili-nne and Sosiani farm. The standard acceptable water colour according to WHO is 15 HU. The study found out that there was no significant difference in water colour from the acceptable level of 15 HU at α =5%. The p values were 0.11 and 0.88 in Maili-nne during the dry season and the wet season, respectively. The p values were 0.25 and 0.064 in Sosiani during dry season and wet season, respectively. The p values were all greater than 0.05 hence no significant difference.

Table 4.17: Paired samples t test for borehole water colour

Site	P value	Std deviation
Maili-nne	0.910	58.077
Sosiani	0.110	51.590

The findings in table 4.17 above shows that the colour values of the water samples from the two sites did not differ significantly during the dry and the wet seasons in Maili-nne estate and Sosiani farm with p value 0.91 and 0.110, respectively. That means even though the sites of samples collection were different and as well activities taking place, the contaminants that may influence the colour of the water samples was the same.

These findings revealed that the color of water samples during the dry season remained homogeneous due to the fact that factors that influence colors during both seasons were the same. During the wet season, surface runoff influence water colour while during dry season dust influence water color thus, the difference during the two seasons may not exist.

Table 4.18: Independent t test for the colour of the water samples

Season	Leven's test for equality of variance	P value
Dry season	0.013	0.174

West season	0.016	0.077

Based on leven's test for equality of variances, the findings shown in Table 4.18, revealed that homogeneity of variances between colours of water samples from Maili-nne during dry season is not assumed (leven's statistic 0.013) though the variation was not significant. Similarly, the leven's test for equality of variance (leven's statistic, 0.016) in water colour during wet season was not assumed but the p value (0.077) shows that the variation was only due to chance and not statistically significant.

Therefore the colour of the water samples do not change based on location and the particular activities taking place within the areas in Maili-nne and Sosiani farm. Physically, ground water is generally clear, colourless, with little or no suspended matter and has a relatively constant temperature. The colour value for the two borehole water supplies remained constantly at 5.00 HU during a study by Ekpong (2013) in Nigeria.

4.4.4 Biochemical Oxygen Demand (BOD)

The study sought to determine the BOD levels of the water samples from the 15 boreholes. Biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period (Penn, 2006). BOD is used as an indication of the organic quality of water.

Table 4.19 shows that the BOD values of the water samples from the sampled boreholes ranged from 1.00 mg/L to 40 mg/L during dry season while during wet season, the BOD values ranged from 0.00 (SB1) to 8.00 mg/L.

BOD values were higher in the dry season as compared to the wet season as illustrated in Table 4.19.

Table 4.19: BOD values of the water samples from the 15 sampled boreholes

	Average BOD Value	
	Mean± Standard deviation	
	Dry Season (mg/L)	**Wet Season (mg/L)**
Maili-nne		
MB1	30±0.87	8±0.15

MB2	15±0.86	7±0.15
MB3	5±0.90	8±0.16
MB4	14±0.91	9±0.16
MB5	25±0.95	8±0.14
Sosiani		
SB6	30±0.98	2±0.14
SB7	35±0.98	7±0.11
SB8	40±0.89	6±0.11
SB9	7±0.49	6±0.12
SB10	2±0.53	5±0.13
SB11	1±0.56	6±0.15
SB12	3±0.56	5±0.18
SB13	4±0.55	ND
SB14	15±0.24	7±0.25
SB15	20±0.80	2±0.26

The amount of organic matter present within water sample and the relative biodegradability of the organics may be estimated by analyzing samples for BOD. Results obtained after analysis are shown in Table 4.22.

Table 4.20: One sample t test for BOD

Site	P value	Std deviation
Maili-nne		
Dry season	0.050	0.983

Wet season	0.00	0.707
Sosiani		
Dry season	0.014	14.77
Wet season	0.00	2.41

Test value 30 mg/L, significant at ∝=¿ 0.05

Table 4.20 present two tail one sample t test for the data acquired in Maili-nne and Sosiani farm. The BOD during dry season differs significantly from the standard value of 30 mg/L with a p value of 0.05. Also during wet season the p value was 0.00 and it is less than the critical alpha set for this study. Hence during wet season, the BOD is significantly different than the accepted value of 30 mg/L.

In Sosiani farm, during dry season and wet season, the p values were 0.014 and 0.00, respectively. It was also less than 0.05 critical alpha set for this study. This means that the BOD of the water samples acquired in this area was significantly different than the acceptable value of 30 mg/L.

This means that the higher BOD recorded during the study was above the standard limit hence water samples was either contaminated with microbes or organic contaminants.

Table 4.21: BOD Paired Sample T Test

	Paired Differences	**t**

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper		df	Sig. (2-tailed)
Maili-nne								
dry and wet season	9.800	9.884	4.420	-2.473	22.073	2.217	4	.091
Sosiani farm								
dry and wet season	11.100	14.663	4.637	.611	21.589	2.394	9	.040

In reference to the table 4.21 paired sample t test was done to ascertain if there was a significant difference between BOD values between dry season and wet season in Mailli-nne and Sosiani farm. From the table it was evident that there was no significant difference in BOD levels in Maili-nne during dry and wet season (p=0.09) while in Sosiani farm, the colour values changed significantly during wet season, and the change was significant statistically with p value of 0.04 . This was attributed to surface runoff.

Table 4.22 Independent sample t test for BOD

Season	**P value**	**Leven's test for homogeneity of variance**
Dry season	0.780	0.192
Wet season	0.002	0.021

When the level of BOD was compared (Table 4.22) to find out if there was a significant difference in the level of BOD between Maili-nne and Sosiani farm during the dry and the wet seasons, an independent sample t test revealed that during the dry season, the level of BOD in Maili-nne and Sosiani farm did not differ significantly; the p value was 0.780 greater than 0.05 and the leven's test for homogeneity of variance revealed that homogeneity of variance was not assumed. On the contrary, during wet season the BOD level value was significantly different in Sosiani farm than Maili-nne with a p value of 0.002 less than 0.05 with a leven's statistic of 0.021. This difference in BOD noted during wet season was due to the fact that rain surface run off influenced BOD of the unprotected boreholes.

Studies carried out by Ndubi *et al.,* (2015) which was conducted in Narok north sub-county, Kenya to analyze physico-chemical properties of water in various water sources in the dry and the wet season to determine water quality for domestic use. Properties analyzed included pH, temperature, DO, BOD, TDS, TSS and total hardness. The results indicated that most parameters fell within the accepted range according to WHO except for the BOD which indicated the presence of microorganisms and hence the water is not fit for human use unless treated prior to consumption

4.4.5 Nutrients

Sulphates and nitrates are essential plant nutrients and their levels in natural water bodies are typically low. Excessive amounts of nutrients can cause water quality problems. The sulphate and nitrate concentrations were determined in the 15 boreholes and their results are shown in Tables 4.23 (sulphates) and 4.26 (nitrates).

4.4.5.1 Sulphates (SO_4^{2-})

Sulphate ion is a polyatomic anion (SO_4^{2-}). Salts, acid derivatives, and peroxides of sulphate are widely used in industry and they occur naturally. Sulphates are salts of sulfuric acid and many are prepared from that acid.

The present study sought to determine the sulphate concentrations for the water samples from the 15 boreholes. The sulphate concentrations of the water samples from the 15 boreholes for both the dry and the wet seasons are presented in table 4.23.

In table 4.23, the findings shows that the sulphate mean concentrations of the water samples from the sampled boreholes ranged from 0.40 mg/L (SB15) to 28.30 mg/L (SB1) while during the wet season, the mean concentrations ranged from 1.06 mg/L (SB8) to 66.44 mg/L (SB9).

Table 4.23: Sulphate concentration of the water samples from the 15 boreholes

Boreholes	Average Sulphate Value Mean ± standard deviation Dry Season (mg/L)	Wet season (mg/L)
Maili-nne		
MB1	2.11±0.54	4.8±1.45
MB2	7.1±0.56	8.4±1.43
MB3	9±0.58	49.29±1.04
MB4	14.92±0.61	10.6±0.91
MB5	4.43±0.61	2±1.42
Sosiani		
SB6	1.11±0.65	1.67±1.03
SB7	0.00	1.2±1.07
SB8	2.90±0.67	1.06±1.00
SB9	5.90±0.71	66.44±1.15
SB10	2.71±0.77	52.27±1.47
SB11	13.9±0.83	5.40±1.52
SB12	6.82±0.94	5.00±1.67
SB13	28.3±1.15	29.79±1.61
SB14	0.52±0.65	19.85±1.01
SB15	0.44±0.66	1.50±1.07

Table 4.24: Independent sample t test for the variation in sulphate between two sites

Season	P value	Leven's statistic
Dry	0.730	0.775

Wet	0.784	4.680

Table 4.24 shows that there was no significant difference in quantity of sulphate during the dry season between Maili-nne and Sosiani farm (p value 0.73). Likewise, during the wet season, the sulphate concentration of boreholes in Maili-nne estate and Sosiani farm was not statistically different, (p value 0.784). Therefore the concentration of sulphate did not differ due to location of the borehole during study. This finding indicates that farmers in Sosiani farm do not use sulphate fertilizers in their farms and even if they use, this compound did not end up in the boreholes carried by rain water or irrigation surface runoff. Ekpong (2013) found out that the total alkalinity ranged from 21.00 to 275 mg/l, salinity ranged from 15.00 to 566 mg/l, chloride ranged from 5.50 to70.00 mg/l, but sulphate was absent in all the water samples. The results obtained showed how elemental compositions vary with lithogy.

Table 4.25: Paired sample t test for sulphates concentration in the sampled boreholes

Site	**P value**	**Std deviation**
Mailli-nne	0.573	0.7910
Sosiani	0.024	8.20

From Table 4.25 it is evident that in Mailli-nne estate, there was no statistically significant difference in concentration of sulphate between dry and wet season p value was 0.573. In Sosiani farm, there was a significant difference in concentration of nitrate between dry season and wet season. The concentration of sulphate was higher during dry season in Sosiani farm than wet season.

4.4.5.2 Nitrate

Table 4.26: Nitrate concentration of the water samples from the 15 boreholes

	Average Nitrate Value	
	Dry Season (mg/L)	**Wet season (mg/L)**
Mailli-nne		
MB1	17.8±1.01	1.70±0.58
MB2	0.41±1.02	1.40±0.92
MB3	2.30±1.84	3.60±1.01
MB4	1.92±1.4	1.50±1.01
MB5	4.61±1.83	8.00±1.41
Sosiani		
SB6	12.90±1.01	6.00±0.57
SB7	22.80±1.02	0.70±0.54
SB8	16.81±1.25	6.60±1.21
SB9	5.92±1.11	3.40±0.01
SB10	1.80±0.11	2.10±1.53
SB11	3.00±0.38	1.60±1.00
SB12	0.31±1.09	3.10±1.62
SB13	3.00±0.24	1.40±0.56
SB14	18.51±0.37	0.30±1.11
SB15	14.00±1.04	3.70±0.84

Table 4.26 shows that the mean nitrate concentrations of the water samples from the 15 sampled boreholes ranged from 0.31 mg/L (SB12) to 22.80 mg/L (SB7) during the dry

season while the during wet season it ranged from 0.30 mg/L (SB14) to 8.00 mg/L (MB5). Water samples from boreholes in Maili-nne and Sosiani areas had a mean nitrate concentrations of 4.32 mg/L and 6.40 mg/L, respectively. Nitrate is a health hazard and a major indicator of the rate of effluent infiltration through the soil.

Table 4.27: Nitrates One sample t Test

	Test Value = 10ppm					
	t	**Df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Dry season Maili-nne	-1.136	4	.319	-2.488	-8.569	3.593
Wet season Maili-nne	.577	4	.595	5.018	-19.121	29.157
Dry season Sosiani	-1.340	9	.213	-3.740	-10.053	2.573
Wet season Sosiani	1.119	9	.292	8.418	-8.607	25.443

The present study also aimed at finding out if there was a significant difference (Table 4.27) in level of nitrates in the two sites of study during wet and dry season. From the table it was clear that there no deviation of the mean level of nitrates from the permissible level of 10 ppm. Hence the level of nitrate during the dry season and as well wet season remained within acceptable limit by WHO. The p values as indicated in the table above were all greater than 0.05 the set critical alpha for the present study.

Table 4.28: Independent sample t test for the nitrate concentration

Season	P value	Leven test for equality of variance
Dry season	0.310	0.281
Wet season	0.790	0.268

From Table 4.28 on independent sample t test, it is evident that the level of nitrates in the borehole water in Maili-nne estate and Sosiani farm during dry season did not differ significantly, (p=0.310) and in the same way, there was no significant difference in the level of nitrate during wet season between boreholes in Maili-nne estate and Sosiani farm, p value was 0.79.

The concentration of nitrates was higher during dry season in Sosiani farm than wet season. This shows that it could be due to fact that intensive irrigation was going on during dry season and a significant quantity of nitrogenous fertilizers was carried away by irrigation surface runoff into the boreholes in Sosiani farm. This led to high level of nitrogen during dry season than wet season. Samie (2013) found high concentrations of nitrates from sampled water in all the boreholes located in farming areas in Ghana**.**

Table 4.29: Paired samples t test on nitrates for the variation in concentration between seasons

Site	P value	Std deviation
Maili-nne	0.417	18.54

Sosiani	0.139	23.77

Table 4.29 shows that the mean concentration of nitrates in Maili-nne did not differ significantly during the dry and the wet season, p value 0.417 greater than 0.05 while in Sosiani farm, the level of sulphate concentration did not differ significantly during the dry and the wet season, the p value is 0.139 greater than 0.05.

This finding indicates that the level of nitrates in all boreholes from Maili-nne and Sosiani remain constantly low whole year round. This suggested the activities going on around these boreholes did not lead to the nitrates contamination of the boreholes during seasons.

Another study by Getabu et al., (2015) on the water quality parameters like dissolved oxygen concentration, pH, conductivity, turbidity, chlorophyll-a, total and soluble phosphate and nitrate concentrations and coliform counts. Nutrient concentrations generally increased from the source of the Nyanchwa -Riana River towards the lower reaches of the river. Soluble nutrient concentrations exhibited the same trend. The total phosphorous to total nitrogen ratio of 1:3 varied from the Redfield ratio of 1:16 commonly found in natural habitats. Observations on the physical and chemical parameters showed levels stressful to aquatic life, with dissolved oxygen concentrations less than 5 mgL^{-1} in some sampling points.

Nitrates, chemical compounds commonly used as fertilizer, can significantly contaminate ground water. On-site residential septic tanks can also be a source of nitrates. Nitrates,

unlike most agricultural and lawn chemicals, do not chemically degrade with time. If more nitrate compounds are applied than can be absorbed by plant root systems, they are likely to contaminate shallow ground water. Nitrate in drinking water can cause health problems in small children, notably a type of anemia called methemoglobinemia, or blue baby disease (Samie, 2013).

4.30: Correlation analysis

Table 4.30: Correlation between bis (2-ethylhexyl) phthalate and physico chemical properties of borehole water

		pH	Turbidity	Colour	BOD	Sulphate	Nitrate	BIS_Phtalate
pH	**Pearson Correlation**	**1**	**.118**	**-.100**	**-.108**	**-.039**	**.255**	**-.291**
	Sig. (2-tailed)		.674	.722	.701	.890	.359	.293
	N	15	15	15	15	15	15	15
Turbidity	**Pearson Correlation**	**.118**	**1**	**.608***	**-.410**	**.586***	**-.325**	**-.323**
	Sig. (2-tailed)	.674		.016	.129	.022	.237	.240
	N	15	15	15	15	15	15	15
Colour	**Pearson Correlation**	**-.100**	**.608***	**1**	**-.652***	**.690***	**-.682***	**-.296**
	Sig. (2-tailed)	.722	.016		.008	.004	.005	.284
	N	15	15	15	15	15	15	15
BOD	**Pearson Correlation**	**-.108**	**-.410**	**-.652****	**1**	**-.674***	**.823***	**.452**
	Sig. (2-tailed)	.701	.129	.008		.006	.000	.091
	N	15	15	15	15	15	15	15
Sulphate	**Pearson Correlation**	**-.039**	**.586***	**.690***	**-.674****	**1**	**-.564***	**-.240**
	Sig. (2-tailed)	.890	.022	.004	.006		.028	.390
	N	15	15	15	15	15	15	15
Nitrate	**Pearson Correlation**	**.255**	**-.325**	**-.682***	**.823***	**-.564***	**1**	**.396**
	Sig. (2-tailed)	.359	.237	.005	.000	.028		.143
	N	15	15	15	15	15	15	15
BIS_Phtalate	**Pearson Correlation**	**-.291**	**-.323**	**-.296**	**.452**	**-.240**	**.396**	**1**
	Sig. (2-tailed)	.293	.240	.284	.091	.390	.143	
	N	15	15	15	15	15	15	15

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.30 shows correlation analysis between physico-chemical properties of water and organic contaminants. From the table, it can be construed that there was a positive moderate significant correlation between colour and turbidity (p=0.016, rho=0.68), turbidity and sulphate concentration (p=0.022, rho=0.586), strong correlation between colour of the borehole water and sulphate concentration (p=0.004, rho=0.690), and BOD and nitrate concentration (p=0.00, rho=0.823).

On the other hand, there was a significant strong inverse relationship between colour of water and BOD (p=0.008, rho=-0.652), colour and nitrate concentration (p=0.005, rho=-0.68), BOD and sulphate concentration (p=0.006, rho=-0.674), and moderate nitrate and sulphate concentration (p=0.028, rho=-0.564)

There was a negative weak correlation between phthalate and pH, turbidity, color and BOD. Furthermore there was a weak relationship between nitrate, sulphates and phthalate.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study concludes that there existed residues of diazinon in borehole number SB9 (0.35 ppm and 0.20 ppm in dry and wet season, respectively), SB12 (1.52 ppm, wet season) and SB13 (2.21 ppm during dry season). The residues of chloropyrifos were detected in one borehole in Maili-nne estate and other three in Sosiani farm only during dry season (MB1 0.129 ppm, MB9, 0.101 ppm, SB13, 0.362 ppm). The mean value level of bis (2-ethylhexyl) phthalate in Maili-nne is 0.67 ppm and Sosiani is 0.59 ppm and they were significantly different than the WHO standard level. Dimethoate was only detected in water samples from borehole SB7 (0.86 ppm) only during the wet season. Sulfotep was only detected during dry season in water samples for borehole SB9 (0.01 ppm) and SB13 (0.03 ppm). In addition dieldrin was only detected in water samples from borehole MB2 (0.29 ppm) in the wet season. From the results, it was evident that there were residues of heptachlor in borehole number MB5 (1.37 ppm) during wet season.

The pH of water sampled from Maili-nne and Sosiani farm boreholes was acidic and not fit for human consumption. The turbidity of water samples was within the ranged set by the WHO. The turbidity did not change during the wet or the dry season. Furthermore, in Maili-nne and Sosiani farm, the colour of the borehole water did not differ significantly based on location of the borehole and seasons of the year. There was no sulphate contamination in borehole water of Mailli-nne and Sosiani farm. The level of nitrates in all boreholes from Maili-nne and Sosiani farm remained constantly low during the wet

and the dry season. The concentration of nitrates was higher during the dry season in Sosiani farm than the wet season. There was a negative weak correlation between phthalate and pH, turbidity, color and BOD. Finally, there was a weak correlation between the levels of nitrates, sulphates and phthalates.

5.2 Recommendations

The study recommends that borehole water users should be informed on the possibilities of the pesticides contaminating borehole water and the possible effects of the same. The national and county governments should put in place water-treatment processes based on the qualitative and quantitative findings. Residents within the affected boreholes should be advised to use safe, clean, and uncontaminated tap water. Boreholes should have lids and barriers in order to prevent surface runoff carrying pesticides from the farms.

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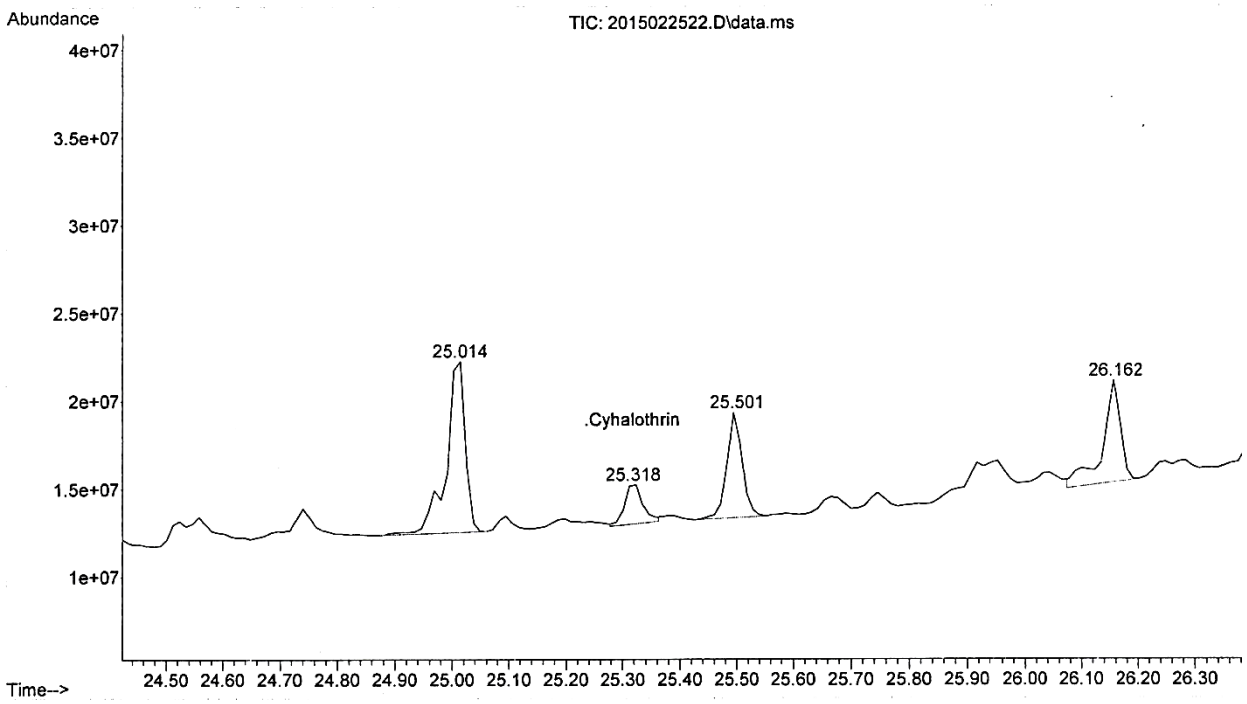
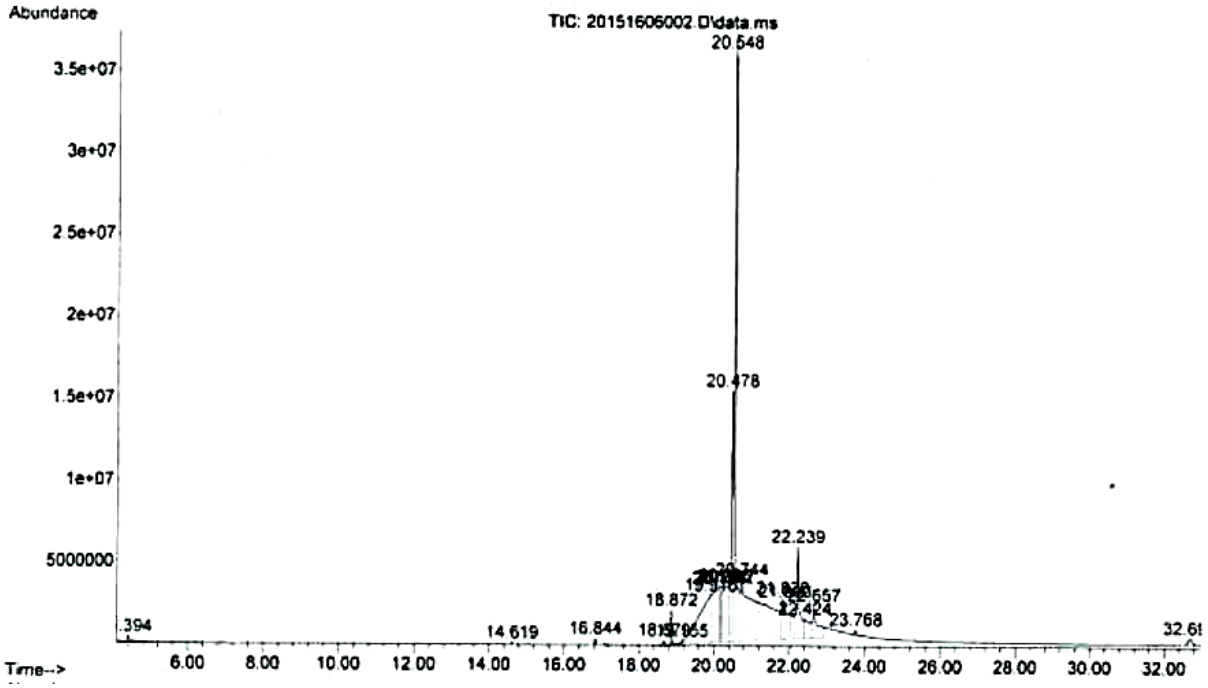
APPENDICES

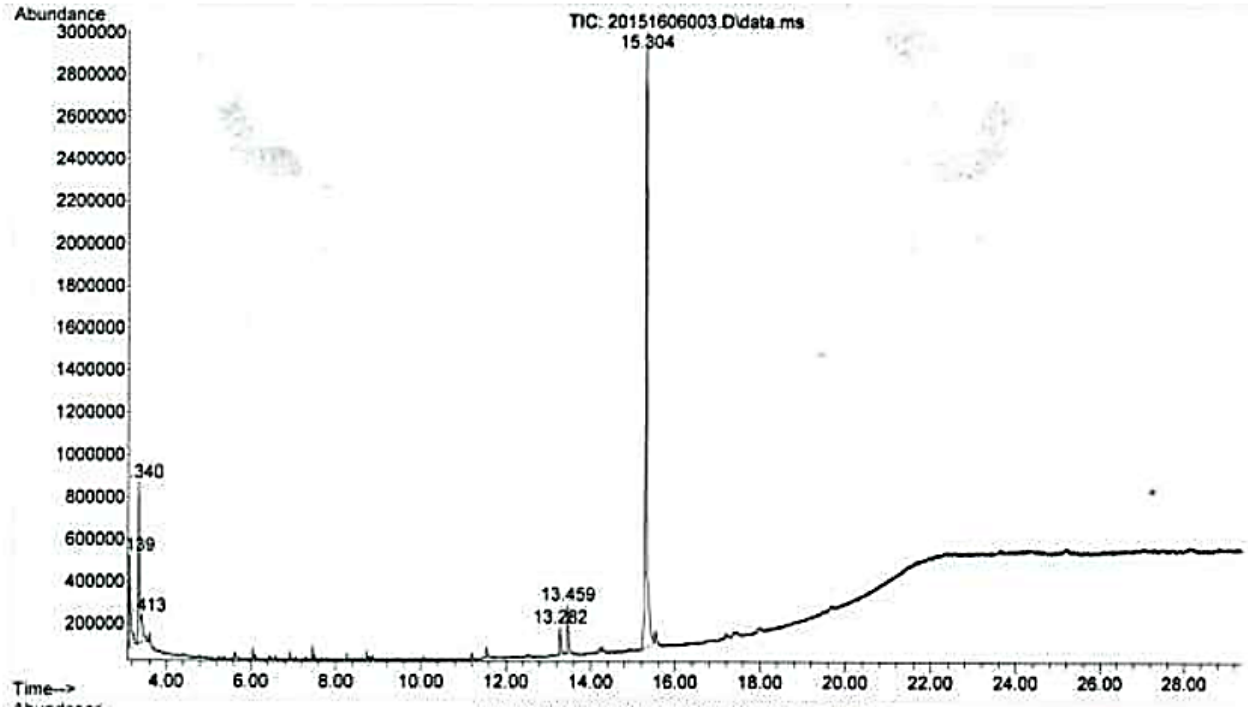
Appendix I: GC-MS Spectrum for water sample from MB1 (Dry Season)



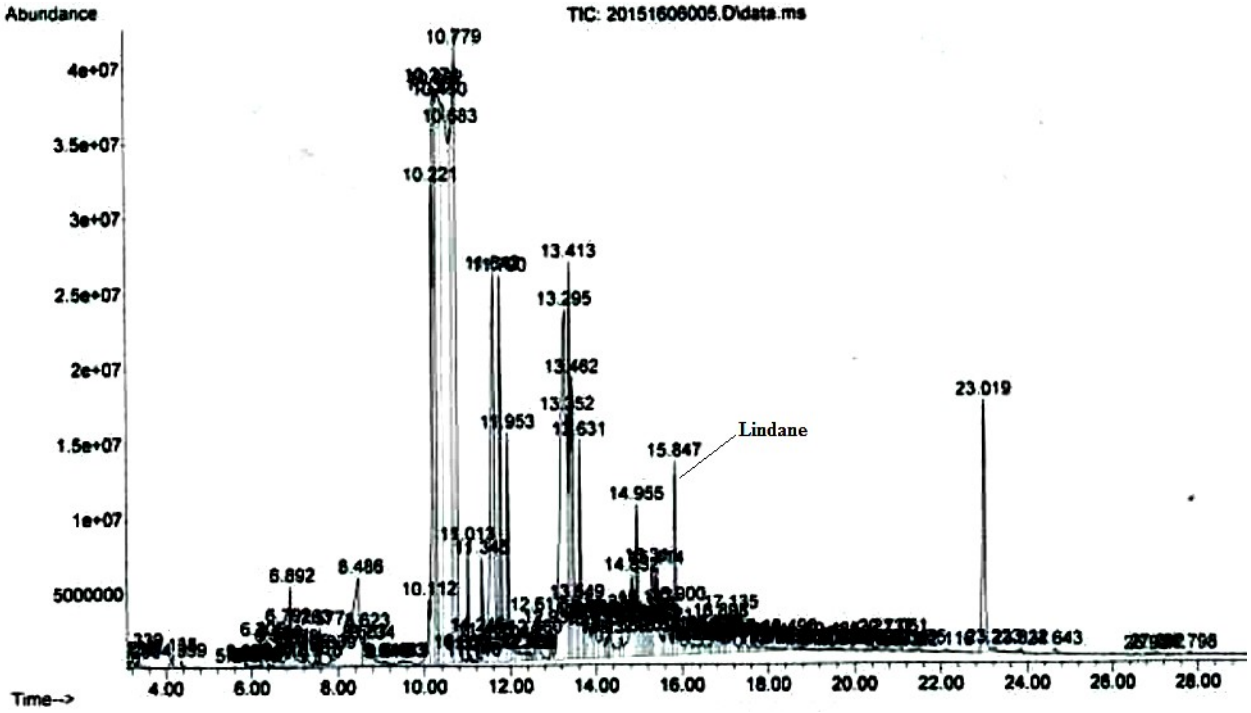
Appendix II: GC-MS Spectrum for water sample from MB1 (Wet Season)



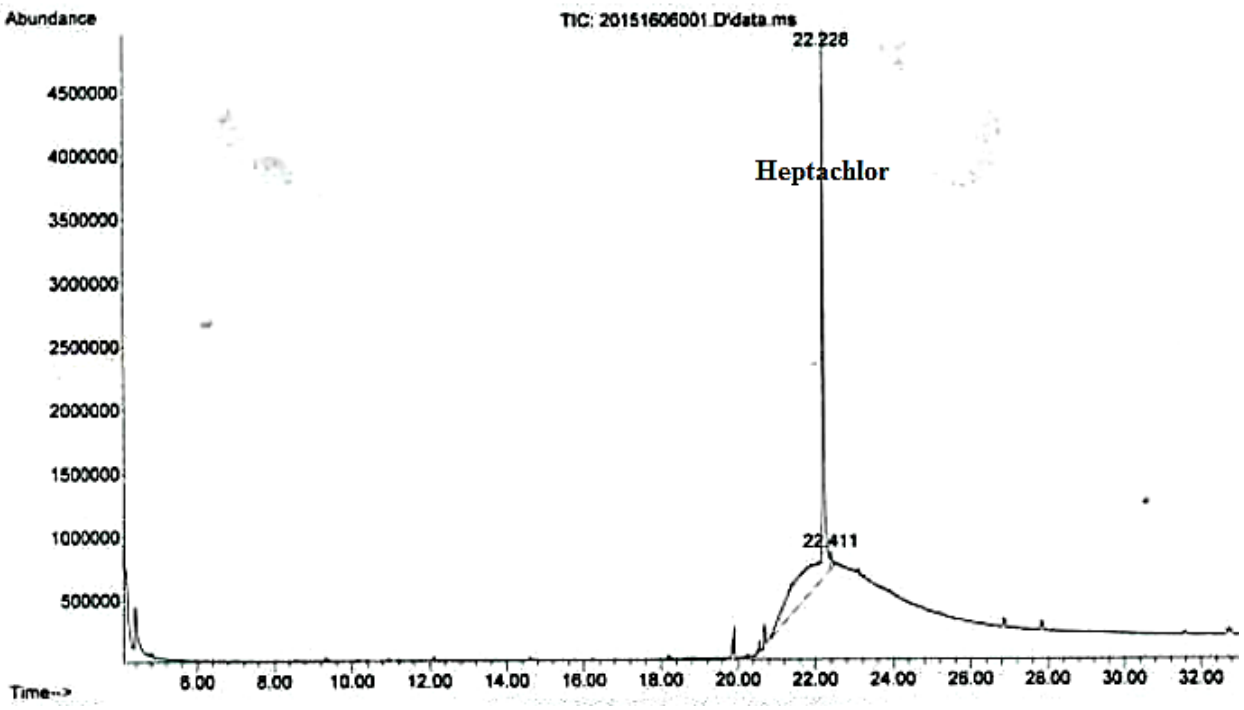
Appendix III: GC-MS Spectrum for water sample from MB2 (Wet Season)



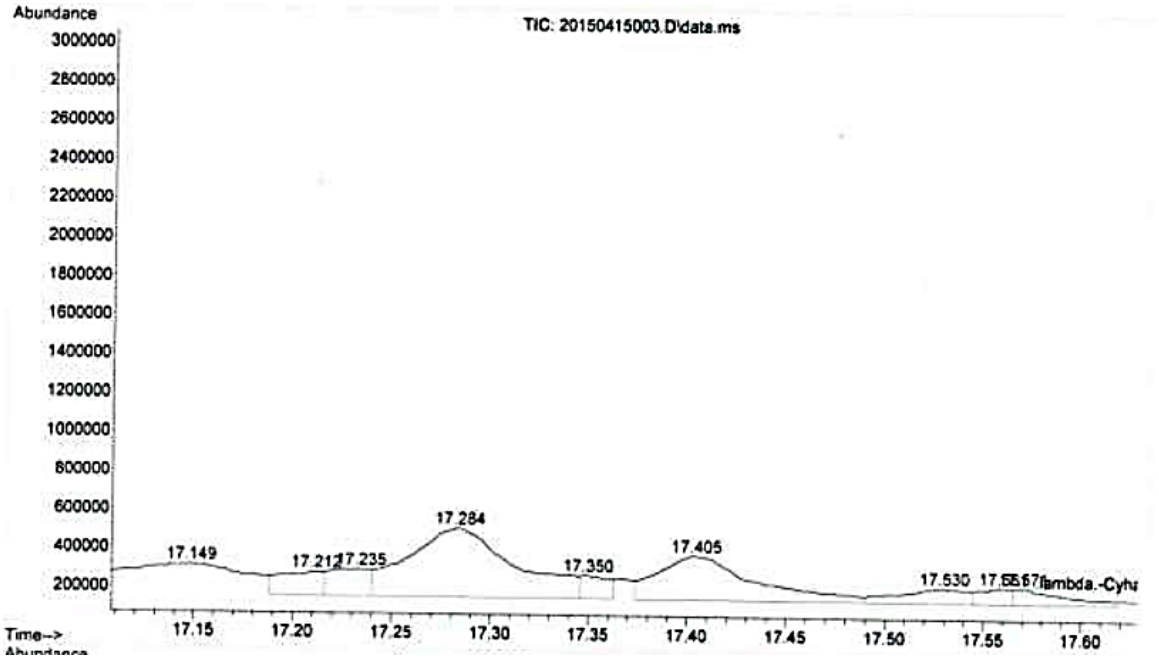
Appendix IV: GC-MS Spectrum for water sample from MB3 (Wet Season)



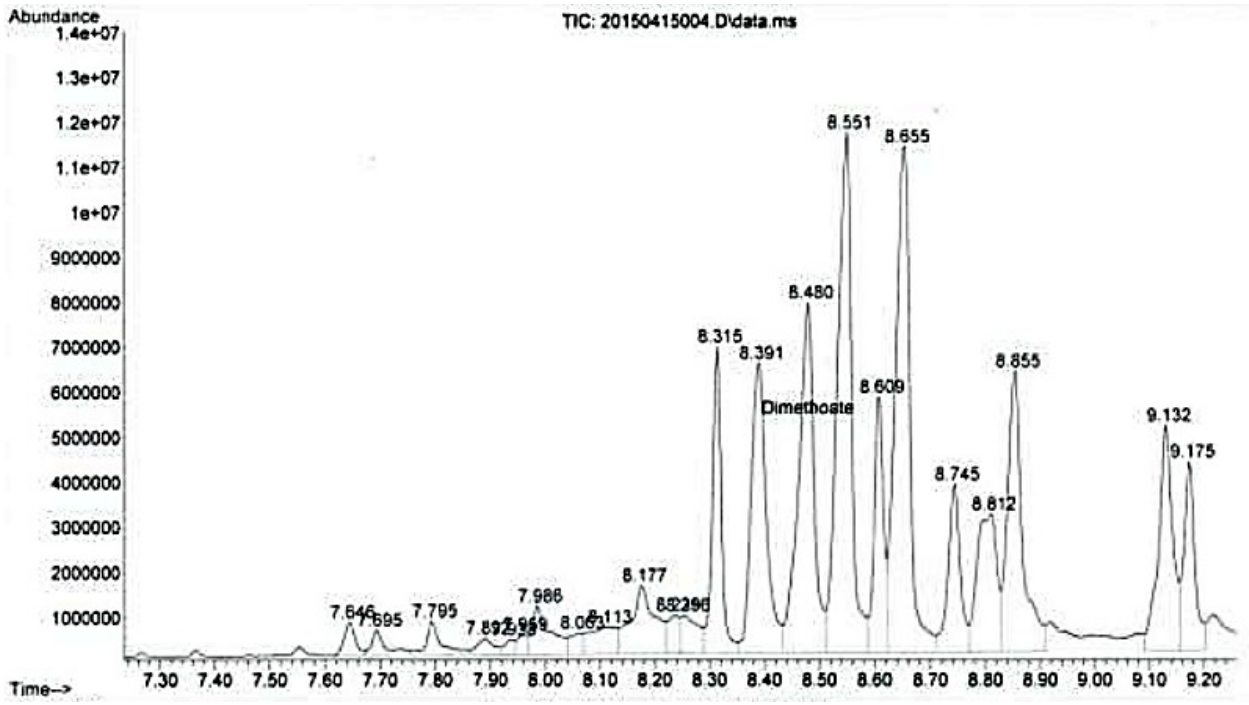
Appendix V: GC-MS Spectrum for water sample from MB5 (Wet Season)



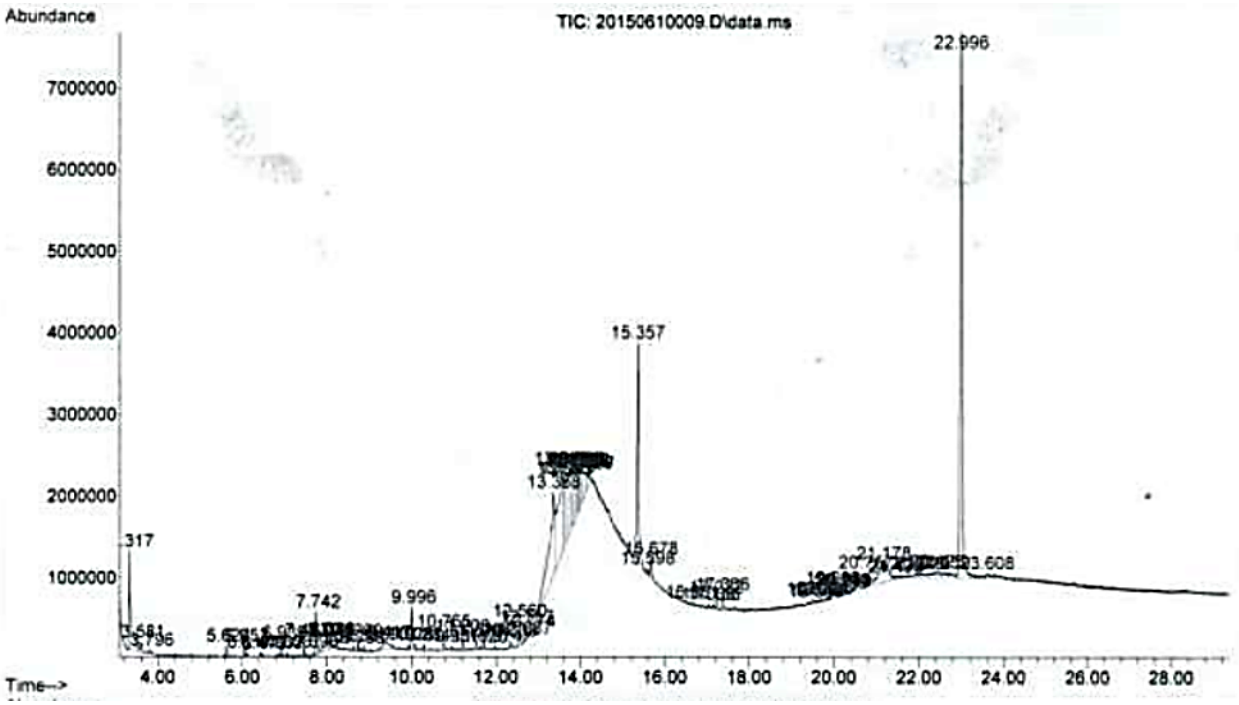
Appendix VI: GC-MS Spectrum for water sample from SB6 (Wet Season)



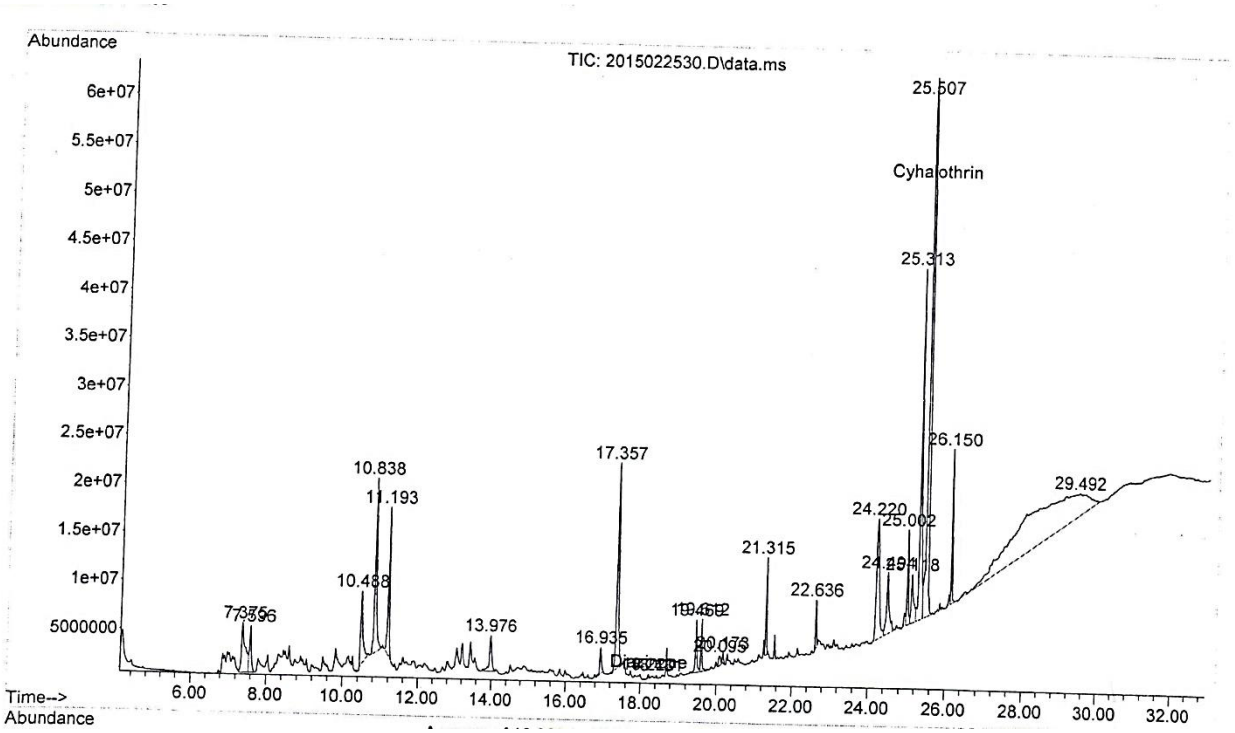
Appendix VII: GC-MS Spectrum for water sample from SB7 (Wet Season)



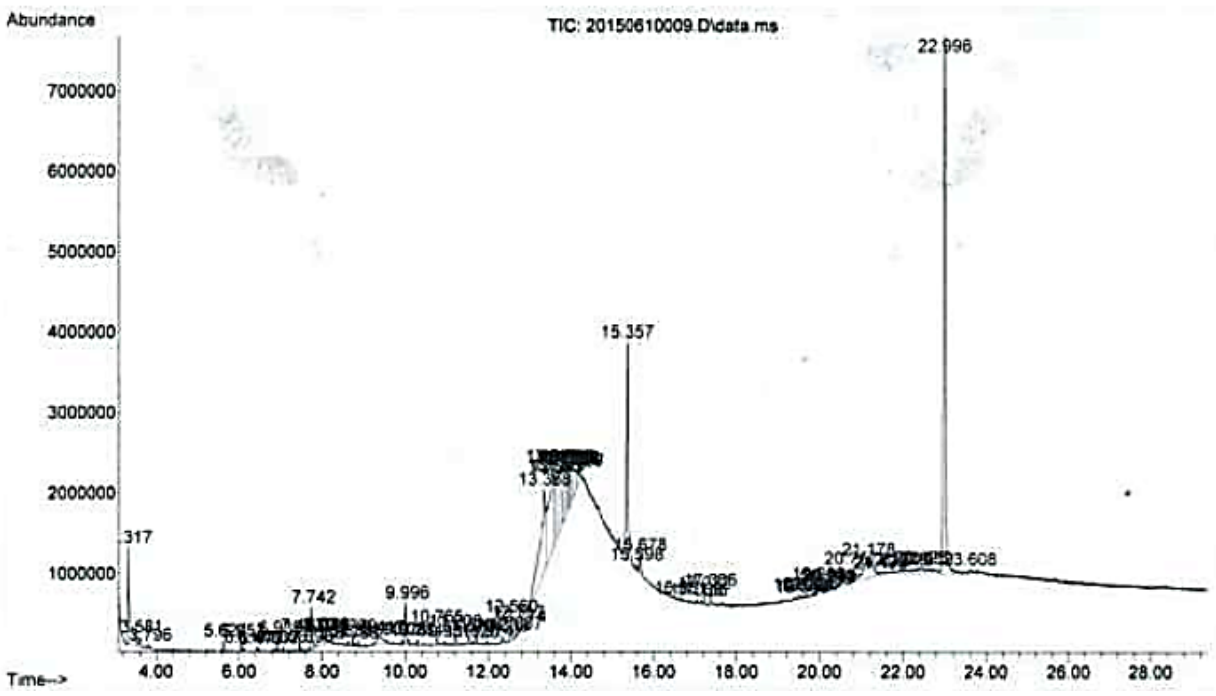
Appendix VIII: GC-MS Spectrum for water sample from SB7 (Wet Season)



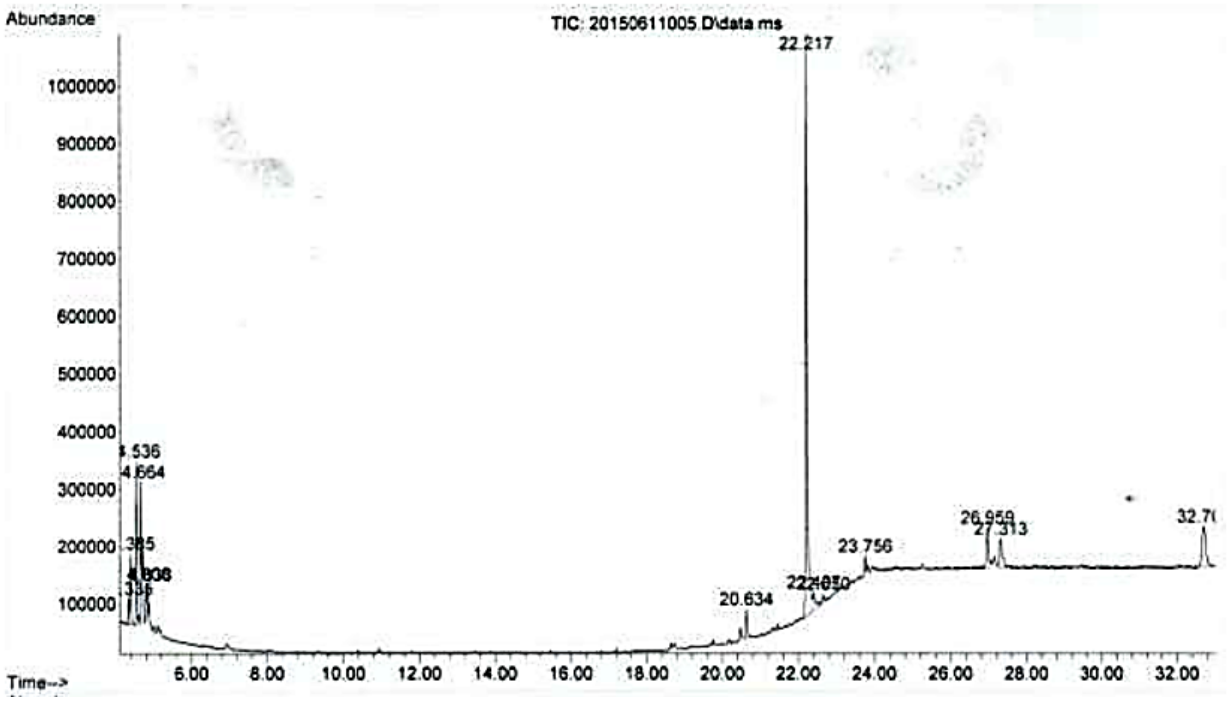
Appendix IX: GC-MS Spectrum for water sample from SB9 (Dry Season)



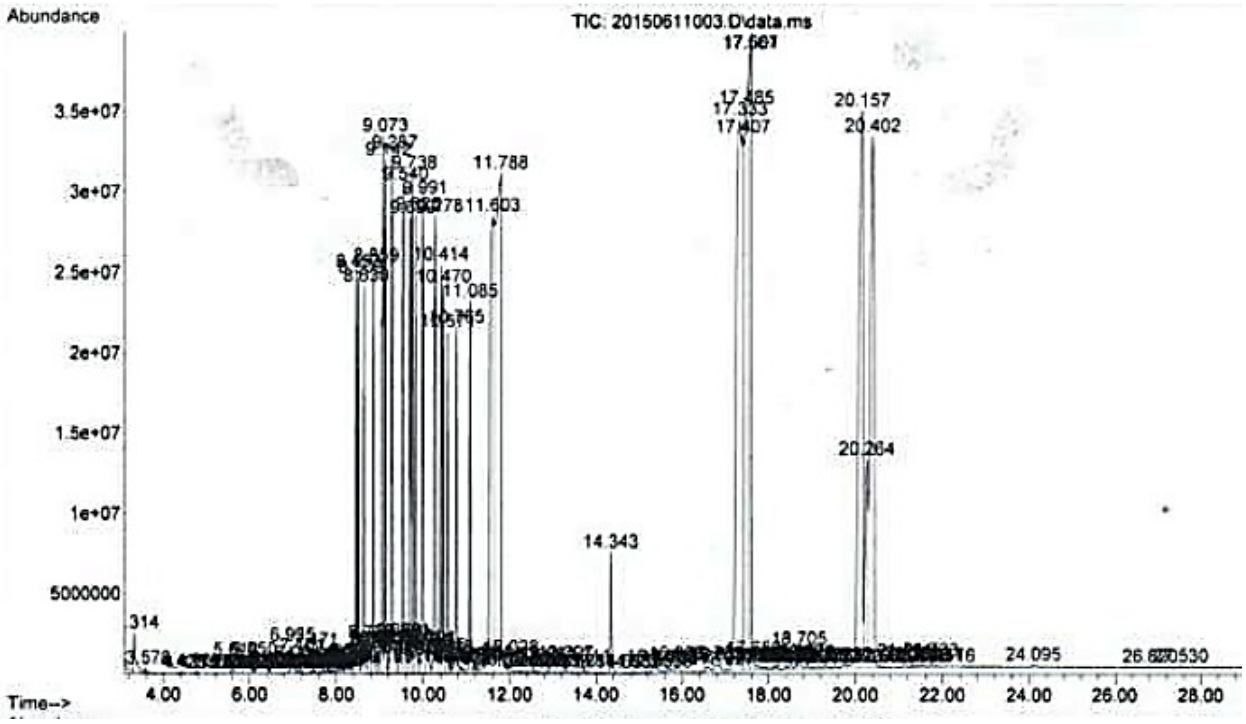
Appendix X: GC-MS Spectrum for water sample from SB9 (Wet Season)



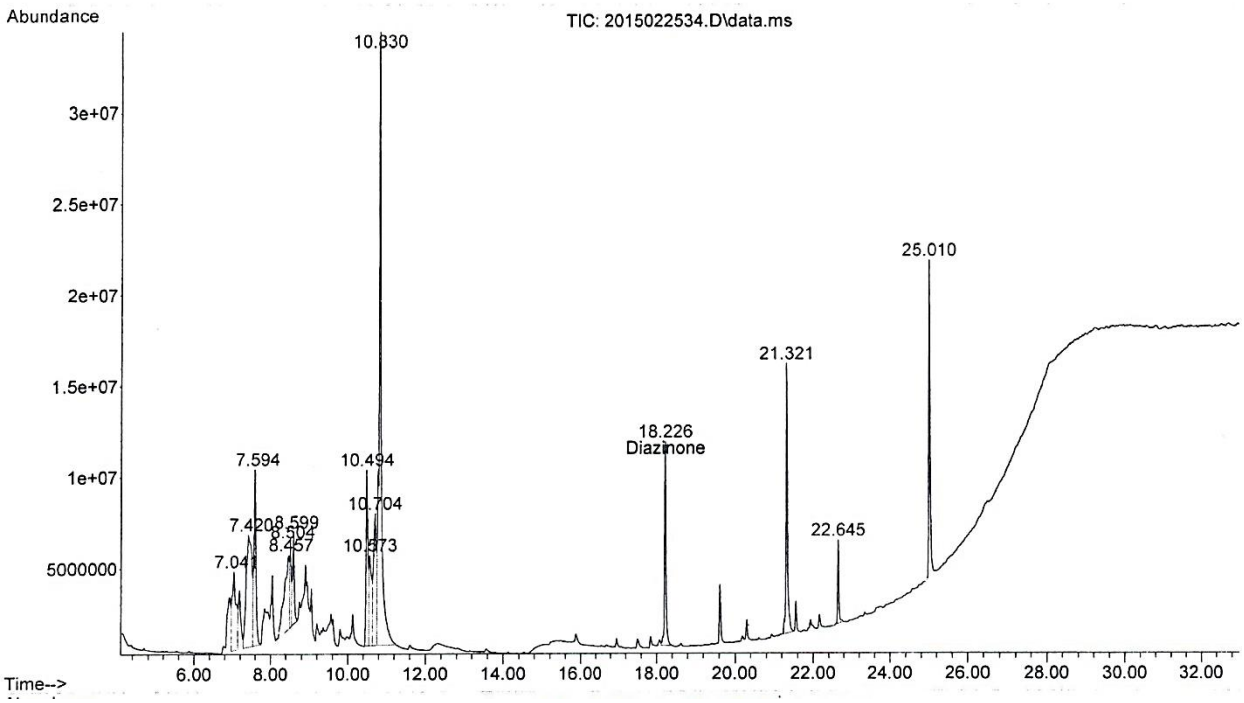
Appendix XI: GC-MS Spectrum for water sample from SB12 (Wet Season)



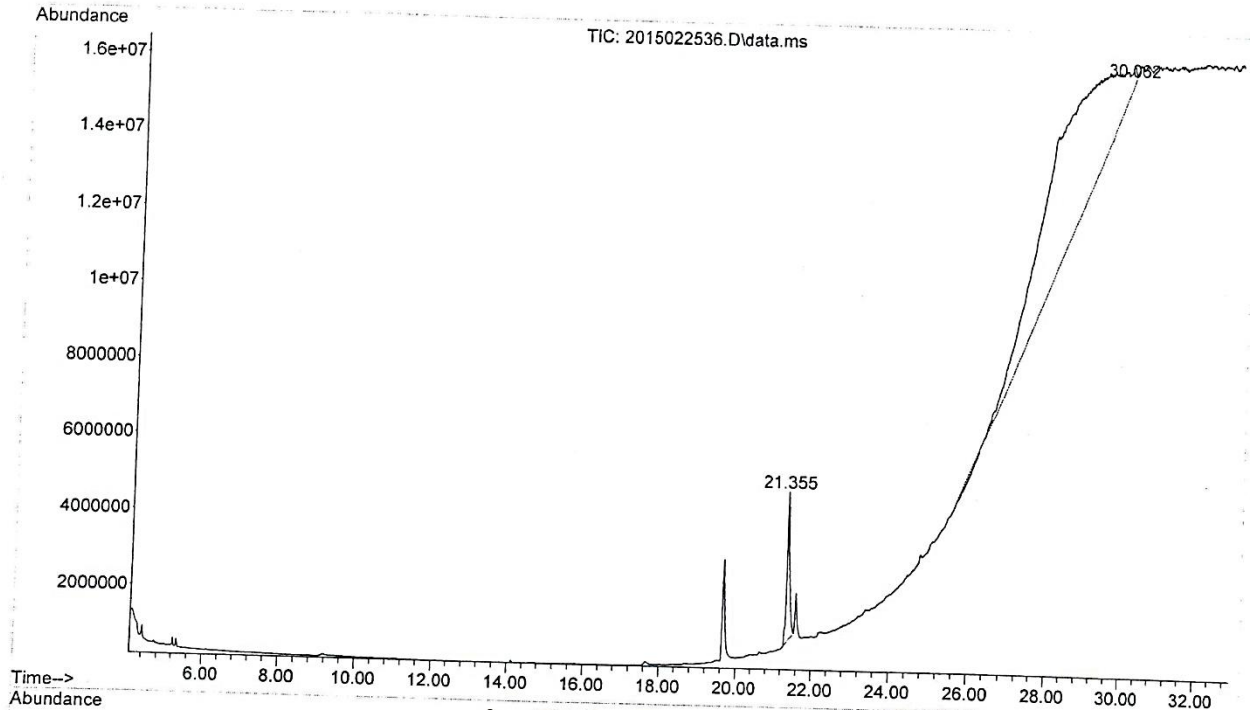
Appendix XII: GC-MS Spectrum for water sample from SB1 (Wet Season)



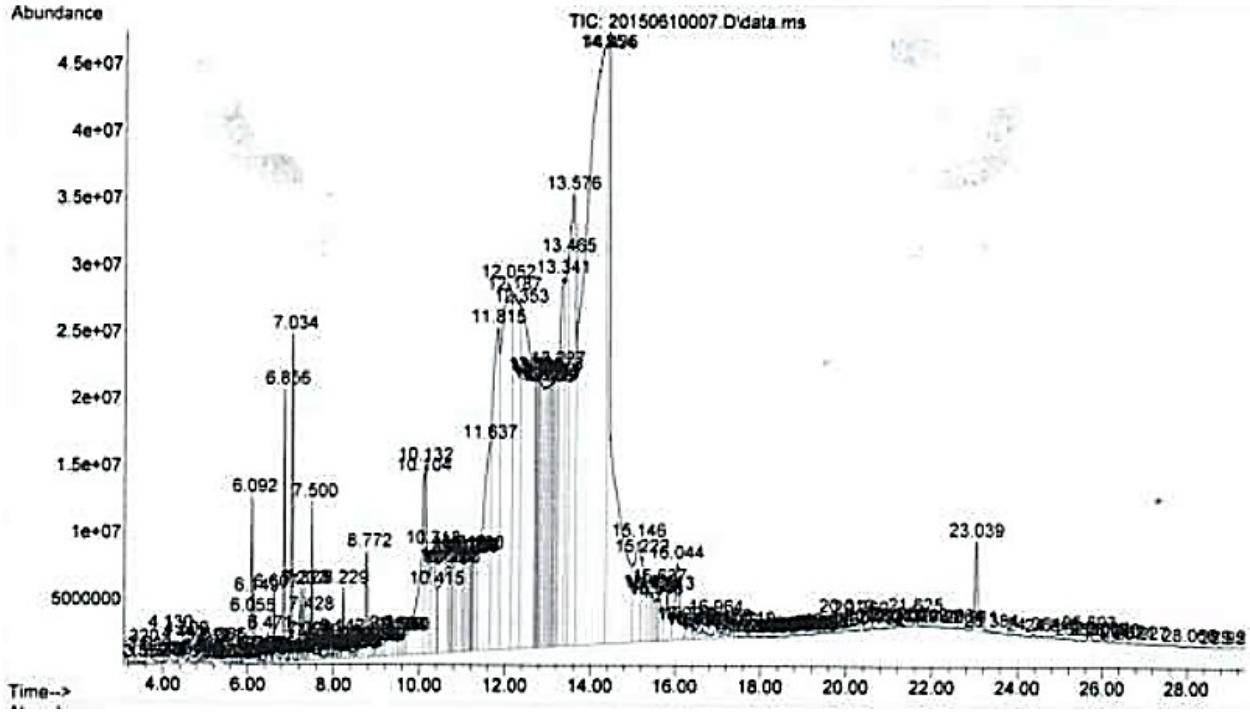
Appendix XIII: GC-MS Spectrum for water sample from SB1 (Dry Season)



Appendix XIV: GC-MS Spectrum for water sample from SB15 (Dry Season)



Appendix XV: GC-MS Spectrum for water sample from SB15 (Wet Season)



Appendix XVI: Maximum Allowable Limits for Different Physico-Chemical Parameters and Organic Contaminants

Physico-Chemical Parameters	**Maximum Allowable Limit by WHO and USEPA**
BOD	30 ppm
Coloration	15 HU
Nitrates	10 ppm
pH	6.5 – 8.5
Sulfates	250 ppm
Organic Contaminants	**Maximum Allowable Concentration**
Diazinon	0.5 ppm
Fenitrothion	0.25 ppm
Chlorpyrifos	0.1 ppm
Dimethoate	0.03 ppm
Malathion	0.19 ppm
Sulfotep	0.1 ppm
Cyhalothrin	0.5 ppm
Dieldrin	0.03 ppb
Lindane	0.3 ppb
Heptachlor	0.1 ppb
Triallate	0.1 ppm
Bis (2-ethylhexyl) phthalate	6 ppb